COMMITTEE OF THE PRIVY COUNCIL FOR
THE ORGANISATION AND DEVELOPMENT OF
AGRICULTURAL RESEARCH

REPORT OF THE AGRICULTURAL RESEARCH COUNCIL FOR THE PERIOD

October 1935—September 1937

Presented by the Lord President of the Council to Parliament
by Command of His Majesty
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THE COMMITTEE OF PRIVY COUNCIL FOR THE ORGANISATION AND DEVELOPMENT OF AGRICULTURAL RESEARCH

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REPORT OF THE
COMMITTEE OF THE PRIVY COUNCIL FOR THE ORGANISATION AND DEVELOPMENT OF AGRICULTURAL RESEARCH

For the period
October 1935 to September 1937

TO THE KING'S MOST EXCELLENT MAJESTY IN COUNCIL

MAY IT PLEASE YOUR MAJESTY,

We, the Lords of the Committee for the Organisation and Development of Agricultural Research of Your Majesty's Privy Council, humbly submit to Your Majesty a Report of our proceedings during the two years from the 1st October, 1935, to the 30th September, 1937. We include a Report from the Agricultural Research Council, established by Royal Charter in 1931 for the purpose of furthering the objects of our Committee; this report, the third prepared by the Council, covers the activities of the Council during the same period and subjoins a review of the research work for the prosecution of which the Council have responsibilities.

During the period under review we received 26 reports of the Agricultural Research Council and its Committees. These reports were considered at two meetings of the Committee of the Privy Council on the 15th December, 1936, and the 21st December, 1937; at the first of these meetings we also received a report by the Secretary on the work of the Council during the year 1935-6.

An increase in the number of members of the Agricultural Research Council from 13 to 15 was authorised in a Supplemental Charter granted in 1934. Sir William Cecil Dampier became a member of the Council in October, 1935, Sir Robert Robertson and Mr. John Smith in February, 1936, and Sir William Wright Smith in July, 1936. Two of these appointments were to fill vacancies caused by retirements from the Council and two to bring the membership up to the full number authorised by the Supplemental Charter. Members who retired by rotation in 1936 and 1937 were eligible for immediate re-appointment and were so re-appointed.

The estimates of the Agricultural Research Council for the financial year 1935-6 were £15,525 for the promotion of research and £4,475 for administrative expenses; the corresponding figures for 1936-7 were £49,000 and £7,900 and for 1937-8 £88,640 and £8,500, of which £38,640 was a re-appropriation from the previous year, during which it was provided but not required for the purchase of the Council's Field Station. The estimates for 1937-8 include a sum of £79,510 for capital expenditure on this Station. These amounts are those provided from the Vote for Scientific Investigation, etc., with equivalent appropriation in aid from the Development Fund. In addition, provision is made on the Vote of the Ministry of Agriculture and Fisheries and the Vote of the Department of Agriculture for Scotland for work in Institutes receiving grants from those Departments, work which the Council desire to initiate or assist by special research grants financed by appropriations from the Development Fund. This provision amounted to £8,052 on the Ministry's Vote and £3,027 on that of the Scottish Department in the financial year 1936-7 and £18,987 and £4,229, respectively, in 1937-8. The total provision at the disposal of the Council in consultation with the Departments of Agriculture for the promotion of Agricultural research was, therefore, £15,525 during the financial year 1935-6, £60,079 during 1936-7 and £111,922 (of which £38,640 was a re-appropriation from the previous year) in 1937-8. The Council are further responsible for tendering advice on the expenditure of the much larger sums placed on the Votes of the two Departments of Agriculture for agricultural research and advisory work, the amounts provided for which, with appropriations in aid from the Development Fund, were £356,466 in 1935-6 and £388,646 in 1936-7.

The second Provisional Note on Administrative Arrangements adopted by the Committee of the Privy Council with the concurrence of the Treasury came into effect in 1935 with a consequential readjustment during the financial year 1936-7 of the financial provision made for special research schemes which the Agricultural Research Council desire to initiate or assist. When the work thus proposed is to be done at an institution which is already in receipt of general aid from one or other of the Agricultural Departments, the agreement of the Department concerned is obtained and the cost is defrayed from the sum placed on the Department's Vote for the Council's special research schemes. In all other cases the grant is made direct to the organisation or individual concerned from the Council's own funds borne on the Vote for Scientific Investigation, etc., or the Council employ their own scientific staff for the work.

The more precise definition of the Council's duties as advisers to the Departments and the Development Commission contained in the Second Provisional Note on Administrative Arrangements has strengthened the Council's advisory and co-ordinating functions. The research programmes of the institutes and other organisations receiving grants from the Agricultural Departments are referred by the Departments to the Council, together with estimates of cost, so that the Council may furnish the Departments with their comments and advice before proposals are submitted to the Treasury. The Council are charged with the duty of securing the co-ordination of all agricultural research financed from the Development Fund; they act as Scientific Advisers to the Development Commissioners, on whose recommendation advances from the Development Fund are sanctioned by the Treasury; and in connexion with the preparation of the annual Estimates they are required to submit to the Commissioners a financial statement analysing the whole provision to be charged on the Fund for agricultural research for the ensuing year. When the provision made available by the Treasury is less than that for which Estimate provision had been proposed, the Council, if necessary and if circumstances permit, advise the Commissioners on the allocation of the provision for expenditure actually sanctioned.

By these means the Council are increasingly able to discharge the duties laid on them of seeing to it (1) that any expansion of agricultural research is directed to the most important needs of the industry; (2) that present and future facilities available at research institutes or elsewhere are utilised to the greatest advantage; and (3) that undesirable duplication of research work is avoided. In short, not only must the Council see that research is directed to the most important agricultural needs of the nation, but they must try to secure that the country gets the best value from the expenditure of the sums voted by Parliament for the prosecution of agricultural research.

These objects are pursued by means which are set out at length in the Report of the Agricultural Research Council to the Committee of the Privy Council which is hereto appended. The Standing Committees of the Council are informed of the work in progress at the various centres of agricultural research. Detailed examinations of particular fields of agricultural research are made. In the period under review the Council's Committee on Dairying and Animal Products carried out a complete survey of dairying research in Great Britain and submitted to the Committee of the Privy Council and to the Departments of Agriculture a comprehensive report on the whole subject. This report, suitably amended for publication, has recently been issued and it forms the basis for the section on Dairying Research in the Council's appended Report. Detailed examinations of the work of various Institutes have been carried out by Sub-Committees specially appointed for the purpose. The places thus examined in the past two years comprise the Rothamsted Experimental Station; the two stations at Long Ashton and East Molling engaged primarily in fruit research; the Plant Breeding Institute, the National Institute of Agricultural Botany and the Horticultural Research Station at Cambridge; the Institute of Plant Physiology of the Imperial College of Science and Technology at South Kensington; and the Institute of Animal Genetics at Edinburgh. Several of these Sub-Committees have presented reports which the Council have submitted to the Committee of the Privy Council, the Treasury, the Development Commission and the Agricultural Department concerned. In other cases the examination was not completed within the period covered by this Report.

In addition to the reports which we have received from Standing Committees and visiting Sub-Committees of the Agricultural Research Council, reports have been received from the technical Committees which the Council have set up to co-ordinate the work in progress in particular fields of animal and plant pathology and concerned with other aspects of agricultural science. Specialist Committees of the Council, mainly composed of members from outside the Council, exercise a general supervision over the work in progress on the major diseases of farm animals and other subjects on which research is being actively prosecuted at several centres, such as the virus diseases of plants, insecticides and fungicides and grass drying. Much of the expenditure of the funds at the disposal of the Council results from the recommendations of these Committees, who not only keep under review the work undertaken as part of the normal activities of the research institutes, but indicate where it needs developing by means of special research grants. Several of these specialist Committees are appointed jointly or in consultation with other bodies such as the Medical Research Council.

In the Council's Report attention is again called to the need for improvement, particularly in the field of animal research, in the supply of sufficient numbers of trained recruits of ability for service in the research institutions. This weakness has seriously hampered development in certain directions such as research on the diseases of pigs. It is probably temporary, and due to circumstances such as the competing attractions of the public veterinary services and private practice. The steps which have been, or are now being taken to increase the numbers and improve the quality of the candidates for employment in the State-aided research institutions should correct it. The rebuilding and enlargement of the Royal Veterinary College at Camden Town recently carried through, the similar steps being taken at the Royal (Dick) Veterinary College in Edinburgh, and the survey now in progress by an Interdepartmental Committee of the whole subject of veterinary education, are all calculated to ensure that the attack on the preventible diseases of farm animals launched by recent legislation will be supported by an adequate body of research on these diseases.

Undue mortality from disease is the most formidable problem in several important branches of the farm livestock industry. Active research on the control of diseases such as Contagious Abortion and Tuberculosis in cattle is in progress. In other matters, especially in regard to pigs and poultry, the Agricultural Research Council consider that research is in urgent need of development. The surveys of pig disease problems described in the Council's Report seem to indicate that the chief immediate requirement is a study of the causes and control of wastage in young pigs. In poultry there has been an alarming rise in mortality during the past 10 or 12 years, the exact causes of which are obscure; until these are better known only palliative measures can be taken. A Committee appointed by the Secretary of State for Scotland and the Minister of Agriculture and Fisheries has carried out an examination of the problems of the poultry industry, and their Report, published after the period covered by this review, invokes the aid of the Agricultural Research Council in the acquirement of more knowledge of the causes of this mortality. Meanwhile the Council have concentrated on the study of two major poultry diseases, one of which, fowl paralysis, has spread co-incidentally with the rise in mortality and may be associated with it.

The Council continue to devote a large proportion of the funds at their disposal to research on animal diseases. Of the special research grants approved by the Council during the two years from the 1st October, 1935, to the 30th September, 1937, more than three-fifths were directed to assist work in this sphere. In addition, a large capital expenditure has been incurred towards the establishment of a Field Station under the Council's direction at Compton in Berkshire. This station is intended to provide facilities for work on a field scale, particularly in relation to problems of animal health, which do not exist at research institutes.

The establishment of this Field Station is regarded by the Agricultural Research Council as a step of major importance towards the provision of adequate facilities for research on a field scale, especially in the supplying of disease-free animals of known history and in the controlling of animal diseases. The need for large scale work on the prevention or control of diseases was represented to the Council by their Committee on *Brucella abortus* infection and was endorsed by the Council and the Departments of Agriculture. The Committee of the Privy Council, after prolonged consideration of the questions of principle involved decided to authorise the Council to carry out work by their own staff in a station under their direct control or elsewhere.

Two primary considerations have been instrumental in leading to the decision to establish the Council's Field Station. In the course of the examination of the Council's scheme of contagious abortion experiments, the desirability of increasing the supply of animals which could with confidence be accepted as being free from certain specified diseases, and whose history had been adequately recorded, had emerged. Secondly, the general survey of all agricultural research in progress in Great Britain made by the Agricultural Research Council had brought to light other instances than the particular case of Contagious Abortion in which facilities for research on a field scale, but under conditions that could not be maintained in ordinary farming practice, were required. It appeared to the Council and to their Animal Diseases Committee that it would be an unwise and uneconomical step to provide at one or more of the research institutes accommodation for experiments on any single animal disease on this large scale, or to divert the energies of an institute's staff to so extensive a series of experiments as were contemplated, for instance, in the testing of vaccination against Contagious Abortion, in which a herd of some 200 cattle were to be involved. It was considered that the best way to meet these needs was to provide a Station where opportunities for experiments on a field scale under strictly controlled conditions would be available, when fundamental and smaller scale investigations conducted at research institutes or initiated by the Council had reached a stage requiring the use of animals in larger numbers than could be accommodated at an institute without detriment to its general programme.

The Field Station at Compton, therefore, is designed to be complementary to the work at the research institutes. It will carry their work a stage further by larger scale testing than they can usually undertake, and provide opportunities for experiments which are at a stage between research institute investigations and farming practice. It will supply disease-free animals of known history to the institutes for their work; it will give hospitality to workers from the research institutes who have work requiring extension to the field scale so far as circumstances permit, and in turn it will refer back for intensive study in the institutes problems that are likely to arise during the ordinary working of the Station. In the course of their management of the estate the Council will also undertake any experiments with pastures and crops which can usefully be done there. If, however, the Station is to be put to the best use, the Council consider that the number of major experiments in progress at the same time must be strictly limited.

The formidable outbreak of Foot-and-Mouth Disease which the country has recently experienced rendered specially timely the review of the work on this disease made by a Sub-Committee of the Council shortly before the outbreak commenced. Intensive work on Foot-and-Mouth Disease has been in progress for a number of years at Pirbright in Surrey under the supervision of a Committee appointed by the Minister of Agriculture. This work was reviewed by the Agricultural Research Council at the request of the Development Commissioners in the light of the experience gained in the period intervening since a similar review had been undertaken by the Council in 1933, of the Fifth Report of the Foot-and-Mouth Disease Research Committee published in 1937, and of discussions with the staff connected with the work. As on the previous occasion, the Council's review indicated that, in spite of the considerable cost and slow progress of the investigations, the right policy was to pursue them in the hope that measures might eventually be found which would make possible some modification of the slaughter policy now in force. Certain proposals were made with a view to making progress more rapid; these included the appointment of a resident superintendent at Pirbright, the improvement in the conditions of service at Pirbright so as to attract and retain a good nucleus staff and the provision of additional accommodation. Steps will be taken to give effect to these recommendations.

Another animal disease that assumed unwonted prevalence during the period covered by this Report is that known as " grass sickness " of horses. An outbreak of this disease in the summer of 1935 is estimated to have killed some 1,500 horses in Scotland and there are indications that it is spreading also in England. Experiments on grass sickness were carried out in 1937 at the research institute of the Animal Diseases Research Association at Moredun with funds specially provided for the purpose on the recommendation of the Agricultural Research Council. They have, unfortunately, not thrown any fresh light on the cause or control of this obscure disease, but intensive research is still in progress.

So much controversy has been aroused by the campaign by health authorities in favour of the pasteurisation of milk that the independent examination at three centres of the nutritive value of pasteurised as compared with raw milk, recorded in the section on Dairying Research of the Agricultural Research Council's Report, is of particular value. The experiments showed that there is no significant difference in the nutritive value of the two categories of milk when given to calves or mice.

It is reassuring to know from impartial enquiry that the process of pasteurisation as an added safeguard against unpreventable sources of infection and post-milking contamination on the farm is unobjectionable from a nutritional point of view. At the same time it must not be forgotten that careless handling of pasteurising plant may recontaminate the milk, and that it is difficult to pasteurise milk which is to be used in rural areas. The ideal is to supply milk from healthy herds, and the freeing of dairy herds from diseases such as tuberculosis, contagious abortion and the like must still be the primary policy of the clean milk campaign.

During the past two years we have received a series of reports of visiting Committees of the Council on the work of a number of the agricultural research stations. Those dealing with the horticultural research stations at Long Ashton and East Malling contained recommendations for maintaining and enhancing the high reputation which, the Council report, these Stations have justly secured. The Council found that the Plant Breeding Station at Cambridge was understaffed and made recommendations for placing it on a more adequate footing.

In regard to the Horticultural Research Station at Cambridge the Council expressed their grave doubts as to the existing facilities in land and site for the work required of such a station. More recently they have taken into consideration, in joint conference with the two Departments of Agriculture, the whole question of research on vegetables and flowers grown for the market, branches of horticulture which, unlike fruit growing, appeared to the Council and the Departments to have suffered from insufficient assistance from research, if exception be made of the glasshouse industry which is well catered for at Cheshunt. This inquiry is still in progress.

Another Committee has been considering a possible extension of the interests of the Agricultural Research Council into the field of research on certain problems underlying the growing of forest trees. This inquiry originated in a report from the Advisory Council of the Department of Scientific and Industrial Research to the Lord President pointing out that there were basic problems at deeper levels than those reached by the research activities of the Forestry Commission, and likely to be of significance in other aspects of research with which the Agricultural Research Council is concerned, such as fruit culture and the economical utilisation of the soil, problems not being investigated by any of the existing research organisations. Research into certain of these problems was required by the Forest Products Research Laboratory of the Department of Scientific and Industrial Research, and the recommendation was made that the Agricultural Research Council should be asked to take the matter into consideration in consultation with the Department of Scientific and Industrial Research and the Forestry Commission. The Committee have recently concluded their deliberations.

A review of the organisation and activities of the Institute of Agricultural Engineering at Oxford fell due in 1937, as the Institute had been re-organised in 1934 on the understanding that its future would be reconsidered after three years. The University of Oxford, after an inquiry into the affairs of the Institute, recommended its continuation on a modified scale and applied for a block grant to cover the cost of its maintenance for a further period of three years. The Agricultural Research Council, after careful consideration by a Committee appointed for the purpose, advised that the Institute for Research in Agricultural Engineering should be maintained at Oxford, but that the position should again be reviewed at the end of the three years covered by the application. The Council report that they regard with approval the University's proposals for securing close contacts with the School of Rural Economy and the Institute for Research in Agricultural Economics at Oxford and for providing facilities for experimental work on a College Farm managed by the School of Rural Economy, where there is a great variety of soil. The grant for the Institute was sanctioned with effect from the 1st October, 1937.

The work of the Council's Committee on the Preservation of Grass and other Fodder Crops has been of much value in determining the potentialities and limitations of the process of artificially drying young grass, a subject which has aroused very wide interest among the farming community. Both through their special crop drying investigator and by direct contacts, the Committee have kept in close touch with the rapid developments in grass drying which took place during 1936 and 1937. A second report was published in 1937 giving very full details of the experience gained up to the end of the 1936 season, when there were plants in operation at some 46 centres, all but five on farms. Many practical, technical and economic problems are still insufficiently worked out, but the Committee have been able to focus attention on these, in consultation with manufacturers, engineers and users.

The Agricultural Research Council's attached Report, covering the fifth and sixth years of their existence, continues to record an increase in their functions and duties, and a steady expansion of their activities. The Committee of the Privy Council are glad to note that close contacts have been maintained by the Council with the Departments of Agriculture, the Development Commission and the Council's sister organisations for Medical and for Scientific and Industrial Research working under the Lord President. The wider powers entrusted to the Agricultural Research Council by the Note on Administrative Arrangements of August, 1935, have been effective in increasing the usefulness of the Council in the co-ordination and development of agricultural research.

HAILSHAM,

Lord President.

E. J. Butler,

Secretary of the Committee of the Privy Council for the Organisation and Development of Agricultural Research.

24th May, 1938.

REPORT OF THE AGRICULTURAL RESEARCH COUNCIL FOR THE PERIOD OCTOBER 1935 TO SEPTEMBER 1937

To the Lords of the Committee of the Privy Council for the Organisation and Development of Agricultural Research.

May it please Your Lordships,

The Agricultural Research Council beg leave to submit the following Third Report upon their proceedings, covering the period from the 1st October, 1935, to the 30th September, 1937.

I.—INTRODUCTION

The Council have been glad to welcome as new members Sir William Cecil Dampier, Sir Robert Robertson, Mr. John Smith and Sir William Wright Smith. Two of these new members were appointed to fill vacancies caused by the retirement of previous members and two to bring the number of the Council up to the full 15 authorised by the Supplemental Charter granted in 1934.

A list of the membership of the Council's various standing and other Committees is given in Appendix I. The Council desire to express their appreciation of the full and valuable co-operation which they have received in the discharge of their duties from a large body of scientific men of standing throughout the country, who have given their asistance by service on these Committees and in other ways.

The administrative business of the Council continues to be discharged in large part by the staff of the Development Commission whose offices the Council share. The increase in the work of the Council has necessitated an increase in the staff and charges on the Development Fund in respect of the administrative expenses of the Council from £4,475 in 1935-6 to £7,900 in 1936-7 and £8,500 in 1937-8. The amounts provided during the same period from the Development Fund as appropriations-in-aid to the Vote for Scientific Investigation, etc., for the promotion of agricultural research directly financed by the Council were £15,525, £49,000 and £88,640 (of which £38,640 was a revote from the previous year), respectively. Furthermore, on the recommendation of the Development Commissioners appropriations-in-aid were made from the Fund to the Vote of the Ministry of Agriculture and Fisheries for work which the Council might decide to initiate or assist amounting to £8,052 in 1936-7 and £18,987 in 1937-8: the similar appropriations made to the Vote of the Department of Agriculture in Scotland during the two years were £3,027 and £4,295, respectively. The Council, under the new Note on Administrative Arrangements, adopted by the Committee of the Privy Council for the Organisation and Development of Agricultural Research with the concurrence of the Treasury, in August, 1935, are now charged with the duty of submitting to the Development Commissioners, in connection with the preparation of the annual Estimates, a financial statement analysing the whole provision to be charged on the Development Fund for agricultural research during the ensuing year. This statement, prepared by the Budget Committee of the Council, showed that the estimated expenditure from the Fund for agricultural research and advisory work in 1936-7 was £456,625.

Towards their expenditure for the promotion of research the Council have to acknowledge generous contributions from the Milk Marketing Board, who have provided a sum of £2,000 annually during the past three years for the development of work on contagious abortion in cattle, and from the Racecourse Betting Control Board, who provided sums of £500 in 1936-7 and £2,000 in 1937-8 for the cost of work on the diseases and disorders of horses, under the supervision of the Council's Committee on Equine Research.

The Council, under the direction of the Committee of the Privy Council and after consultation with the Ministry of Agriculture and Fisheries and the Department of Agriculture for Scotland, obtained Treasury sanction for the purchase of an estate to serve as a Field Station under their own control. After prolonged search they acquired the Compton Manor Estate of 1,500 acres on the Berkshire Downs, about 16 miles to the west of Reading, and entered into possession of the estate in October, 1937. The objects of the Council in establishing a Field Station of their own are twofold and have been adopted after a careful survey of the existing facilities for agricultural research. In the first place it is hoped to supply from Compton to agricultural research institutions for experimental purposes animals of known history and free from disease; for these there is a demand which it is becoming increasingly difficult to meet. The Council, therefore, also bought the pedigree herds of Ayrshire and

Friesian cattle on the estate, most of which had for some years been under expert supervision by two veterinary members of the Council's own Committees. The herds are mostly free from the major cattle diseases and in process of being completely freed from them. A herd of some 300 tubercle-free Large White pigs was also taken over with the estate. Secondly, the Council desire to fill a gap in the existing facilities for research by providing opportunities for experiments on a field scale under strictly controlled conditions. In the Council's last Report the proposals made by their Committee on *Brucella abortus* Infection in Animals and Man for the initiation of extended testing of measures for the control of Contagious Abortion in cattle, on a farm centre under the direct control of the Council, were detailed. The Committee desired that facilities should be provided for large scale work on Contagious Abortion with an adequate area of land adjoining the special buildings, and cattle owned by the Agricultural Research Council and therefore under the Committee's full control. They estimated that some 200 cattle would be required for the experiments on this disease, and recommended that the experimental animals should be kept in a number of isolation units which would occupy a considerable area of land. The general survey of research facilities carried out by the Council had brought to light other instances in which experiments on a large scale, but under conditions which could not be secured in ordinary farm management, were required. While the research institutions are fitted to undertake experimental work requiring the use of small animals and experiments on large animals in which the numbers of animals can be limited, the attempt to provide accommodation and facilities for experiments requiring the use of large animals in considerable numbers at any one or more of the research institutions seemed to the Council to be uneconomical and to carry with it the risk of diverting the energies of the institution to the detriment of its general work.

At Compton it is the intention to provide opportunities for experiments when the work at the research institutions has reached a stage for large scale trial; in applied research this stage is a crucial one. It is not intended to develop at Compton a self-contained Research Institute. The resident scientific staff will be small and the laboratories will be designed to provide accommodation sufficient for this staff and for visiting workers from research institutions. It is hoped that, when circumstances permit, members of the staffs of research institutes may themselves bring their inquiries to the final stage of large scale testing at Compton. At the same time, if the Station is to be put to the best use, the number of major experiments in progress at the same time must be strictly limited. Probably for the time being only one series of large scale experiments upon cattle, pigs and poultry, respectively, should be undertaken concurrently. With cattle the first group of experiments will be concerned with Contagious Abortion and will involve the testing of various vaccines, which as the result of the current work on this disease at the research institutes, appear to merit full scale trial. This work cannot start until the necessary isolation units have been built and it may last for five or even for ten years; but the fact that animals known to be free from infection by *Brucella abortus* are available at Compton will shorten the period of experiment by three or four years. With pigs it is proposed to use the herd mainly for certain types of work not being done elsewhere and not involving the introduction of infectious disease nor interfering unduly with the commercial running of the herd. The herd will be maintained so far as possible under optimum commercial conditions and full records and close observations, particularly in regard to the losses amongst small pigs, will be kept for the first year. With poultry, stocks will be maintained to test the hypothesis that susceptibility to fowl paralysis is inherited in certain strains of birds; for this purpose birds of known pedigree, which have been under examination for reaction to the disease in two inbred lines at the Wellcome Laboratories at Beckenham, will be used.

Small animals must be bred on a considerable scale for use in connection with the experimental work at the Field Station. It is proposed to breed a surplus of healthy small animals for supply to research institutes, which have of recent years often experienced difficulties in obtaining sufficient numbers to meet their requirements. This supply of healthy small animals will be a useful adjunct to the supply of disease free large animals for experimental work at the institutes which, as mentioned above, is one of the major purposes of the Station.

In the course of their management of the Estate the Council will also undertake any experiments with pastures and crops which can usefully be done there.

As Director of the Field Station the Council have selected Mr. G. W. Dunkin, M.R.C.V.S., D.V.H., who had been for a number of years Farm Superintendent of the Medical Research Council's Farm Laboratories at Mill Hill. Mr. E. Macmillan, who had been associated with the management of the Compton Estate for many years, was appointed Farm Manager.

In the following pages an account is given of the research in progress in Great Britain in the various branches of agricultural science in so far as the research is aided from State sources. The Agricultural Research Council's duties and responsibilities in regard to their functions as advisers to the Development Commissioners, on whose recommendations advances from the Development Fund for the financing of agricultural research are sanctioned by the Treasury, are defined in the Second Note on Administrative Arrangements approved in August, 1935. The Departments of Agriculture, while continuing unchanged their existing administrative relationship with Agricultural Research Institutes, University Departments of Agriculture and Agricultural Colleges, undertake to provide the Research Council with all information at their disposal regarding research grants, and to receive the Council's criticism or advice on them. This arrangement entails, in particular, the forwarding of all programmes and estimates of cost of the research work of the institutes and other research centres receiving Development Fund grants in time to enable the Council to comment or advise upon them before proposals are submitted by the Departments to the Treasury each year. Thus, in practice, all schemes for, and all expenditure on agricultural research, apart from a very limited number of items not financed from the Development Fund, come under the scrutiny of the Agricultural Research Council; indeed, it is becoming more and more usual for the Departments to consult the Council on all their activities in the field of agricultural experimentation and research. The extent and diversity of the work in progress, as indicated in the following sections of this Report, make the Council's task no light one.

New Committees of the Council were set up during 1936 to develop and co-ordinate research on the relationships between nutrition and disease and on the diseases and disorders of horses.

The Committee on Nutrition in Relation to Disease was established in consultation with the Medical Research Council to replace an earlier Sub-Committee. It includes in its membership some representatives whose interests are mainly in the field of human nutrition, for much work on nutrition is of value equally to animals and man, and there may be much to be gained by contact with research on human nutrition when the bearing of nutrition on susceptibility to infective diseases is in question. The Committee on Equine Research had its inception in an approach to the Ministry of Agriculture and Fisheries by the Racecourse Betting Control Board, which led to a Conference convened by the Council with representatives of the Ministry and of the Board, who intimated the desire of the Board to support financially research on the diseases of horses, especially thoroughbreds. Further inquiries and consultation with veterinary research workers and practitioners led the Council to recommend research on certain selected problems for which the necessary funds have been provided to the Council by the Board. The Equine Research Committee was set up to coordinate and supervise this work and to plan further developments. A separate Sub-Committee has been formed to keep in touch with the work on " grass-sickness " of horses in Scotland and to advise on further investigations of this obscure disease.

The Sub-Committee on Soil Surveys of the Plants and Soils Committees has been actively engaged during the period from 1935 to 1937 in an inquiry into the present position of soil surveying in Great Britain and the organisation necessary to place the survey on a proper footing. This Sub-Committee reported after the period covered by this review. Other Committees have been engaged in an examination of the need for extending research on vegetables and flowers grown for the market (appointed jointly with the Departments of Agriculture) and for research affecting the growing of forest trees, whether of a more fundamental character than that which is undertaken by the Forestry Commission or of such an intermediate nature between forestry and agriculture as to constitute a sort of no-man's-land between the two, not adequately served by biological research.

The Council have appointed several specialist officers to their own staff during the period covered by this Report. Mr. E. J. Roberts was appointed to work part-time under the supervision of the Committee on the Preservation of Grass and other Fodder Crops from the 1st April, 1936. Mr. F. W. Priestley was appointed from the 1st August, 1936, to aid Dr. A. D. McEwen at Wye College in work on contagious abortion under the supervision of the Committee on *Brucella abortus* infection. Mr. R. S. Roberts was taken on to the Council's staff from the 1st October, 1936, to continue the survey of sheep diseases which he had been carrying out under the supervision of the Committee on Braxy and Braxy-like diseases of Sheep. Mr. C. Horton Smith was appointed for work on the Coccidia of poultry under the supervision of the Committee on Fowl Paralysis and similar diseases and on Coccidiosis from the 15th March, 1937. The Council desire to express their thanks for the hospitality and other facilities which have been accorded to these members of their staff in the various laboratories of the institutes at which they have worked.

It will be seen that the responsibilities and activities of the Agricultural Research Council have continued to expand during the period covered by this Third Report of their proceedings. The more precise definition of their responsibilities contained in the Second Note on Administrative Arrangements, the acquisition of a Field Station under their own control, and the appointment of scientific staff, have all been developments of major importance in the history of the Council.

II.—AGRICULTURAL ECONOMICS

In the Second Report of the Agricultural Research Council an account was given of the development of research in agricultural economics in this country. It was shown that the development had been almost entirely in the post-war period, and that difficulties had arisen because workers had had to be trained as the scheme developed, and that they had to devise their own methods of research and collect the necessary data on which to work as they went along. It was indicated that the efforts to secure a measure of co-ordination in the work in England and Wales had not been very successful and the hope was expressed that the efforts which were being made to secure more co-operation between the different centres would be successful.

Research in agricultural economics in England and Wales is carried on at one research institute—the Agricultural Economics Research Institute, Oxford—and at eleven centres—Universities or Agricultural Colleges—to which the Advisory Economists for the eleven regions, into which the country is divided, are attached. The Advisory Economists are naturally more concerned about subjects which are of most interest to those engaged in agriculture in their regions, and they direct their research to those problems upon which they are likely to be asked to advise. The diversity of farming conditions in this country will always provide ample scope for regional work of this character. There are, however, enough problems in agricultural economics common to all regions for which the collection and analysis of data by uniform methods are desirable, to justify efforts for co-ordination between the different centres, and during the past two years two major schemes have been in operation.

The first of these schemes is an investigation into the costs of milk production in England and Wales, which was financed with the help of a grant from the Milk Marketing Board. " The object of the scheme was to obtain and disseminate financial and other economic data of general importance concerning the milk industry in England and Wales. The information thus provided was to be used in research and advisory work to improve the efficiency of milk producers and to benefit the industry in general." All the advisory centres and the Agricultural Economics Research Institute, Oxford, are co-operating in the work. The scheme is controlled by the Conference of Agricultural Economists which appointed a Sub-Committee to deal with all questions of technique, to supervise the form of records, to draft the National Report to be prepared by the Agricultural Economics Research Institute from the returns made from the individual provinces, and to deal with other matters of common interest. It was hoped to obtain records from 600 farms adequately distributed throughout the country and so selected as to represent the different types of milk production. Each Advisory Economist uses his own discretion in obtaining suitable farms for the purpose of the investigation. The records have to be kept in the first instance by the farmers and the primary returns for each area are prepared by the Advisory Economist and are then sent on to the Oxford Institute where the material for the whole country is tabulated and summarised and the necessary analyses made.

The work began in the autumn of 1934 and the first Report covering the eleven months to 30th September, 1935, was published in the autumn of 1937. It is an Interim Report and the Conference of Agricultural Economists have issued it with a warning that care must be exercised in drawing inferences or deductions and that hasty generalisations must be avoided if the scheme is to be of real service to those concerned. The total number of farms co-operating for the years 1934-35 was 631, carrying a total of 20,545 cows. Thus it can be fairly claimed that the sample of farms is the best which has been made available so far for the study of milk production problems in this country and that a considerable amount of light will be thrown on many problems of milk production as further Reports are issued, as they will be, with less delay than was necessarily involved in producing the first Report.

In any investigation of costs of production of one commodity in a system of mixed farming such as is general in this country, the money costs disclosed must be subject to certain important qualifications. Certain arbitrary assumptions have to be made in allocating the share of fixed costs for the farm as a whole to the commodity under investigation, and in the values to be assigned to products of other departments which may be used as the raw material in the production of the commodity studied. Home grown foods and grazing, for instance account for half the costs of food on most farms producing milk, while family labour accounts for twenty-five per cent. of the labour cost. In considering the money costs of milk production due allowance should be made for these assumptions.

But keeping these qualifications in view there is much information of a tentative character in the first report. In the group of farms (490), which sell milk wholesale, the comparison of costs shows how widely different are the methods followed in production. After making a credit for calves and manurial residues of foods, the net cost of producing milk on the farm was 9·41d. per gallon, exclusive of management and interest on capital. The range for the individual net farm costs was from 5·2d. to 18·1d. per gallon, a spread of 12·9d. Out of the total of 490 farms, 264 had a cost lying between 8d. and 11d. per gallon, and approximately 75 per cent. of the farms had costs below 11d. and these produced 80 per cent. of the milk.

Other factors discussed in the report are the effect of level-delivery contracts in stimulating the production of milk in winter and the higher costs involved, the influence of the size of the herd on cost of production, and the influence of the yield per cow. As the investigation proceeds we may expect further enlightenment on these and other aspects of milk production.

The value of the scheme, however, is not only in the information secured by the analysis of the data as showing the differences in methods of milk production and the comparisons which can be made between the costs under different methods and in different regions of the country. From the reports of the Advisory Economists it is clear that considerable use is being made of the records for advisory purposes. An increasing number of farmers are having their attention directed to methods of reducing costs of production. As would be expected there is a wide range in the responses of the individual farmers co-operating and there are differences in the responses in different regions as shown by the reports of the Advisory Economists, but the reports in general show an increasing interest on the part of producers, and an encouraging number are putting the knowledge they have acquired by recording to practical use. Some of the Advisory Economists are also using the data collected in their regions for individual researches into certain problems of production.

In our last Report we welcomed a proposal which was then under consideration for an extensive inquiry into the economic position of agriculture in England and Wales. The scheme was approved by the Development Commissioners who agreed to set aside a sum of £3,300 per annum for five years to enable a survey of farm management to be carried out during that period. A Farm Management Survey Committee was set up, on which the Agricultural Research Council was represented, to work out the details of the scheme, which was then submitted to the Conference of Advisory Economists and adopted by the Conference.

The aim of the scheme is to collect full data on the crops, livestock, equipment and labour, with the purchases and sales and other relevant information on some 2,000 farms in England and Wales. The quota assigned to each of the eleven regions was 200 farms. To secure a representative sample each Advisory Economist was asked to make a selection of farms of different types which would be representative of the principal types to be found in the region. The data could either be secured from financial accounts, where these existed, or by the survey method.

In the first year for which data were collected 10 of the Advisory Officers co-operated and returns for some 1,600 farms were secured. Those centres which had been carrying a considerable number of financial accounts as part of their regular programme had little difficulty in securing their quota, but those which had to start from the beginning found they had to canvass a large number of farmers before they managed to find representative farms which could be surveyed. In the second year all the centres are co-operating and the number of farms aimed at should be reached.

The detailed information is gathered by the Advisory Economists and their assistants, and summary sheets are prepared on uniform lines which are then sent to the Agricultural Economics Institute, Oxford, for scrutiny, tabulation and analysis. That work was in hand for the first year's returns at the end of the period under review in this Report. The use that can be made of the data will depend upon the result of the analysis. Groupings, as, for example, by regions, types of farming, and size of farm may add considerably to our knowledge of farm management, but perhaps the most useful information of a general character will be the trends shown from year to year in farms in the same groups. The fact that data are being collected for the first time for an adequate sample of farms throughout the country cannot fail to give us a more accurate picture of farming in England and Wales than we have had, and should provide some factual foundation for the consideration of public policy, the need for which has become urgent now that "planned" policies are being so frequently applied to agriculture.

Two large schemes such as the Costs of Milk Production, and the Farm Management Survey throw upon the advisory centres a great deal of work of a routine character in the collection and summarising of data, and naturally some apprehension has been expressed as to the danger of the Advisory Economists being swamped by the mass of this routine work, to the detriment of their research work. That is a danger which must be guarded against. A fair balance should be maintained between the demand for the collection of data on a basis wide enough to serve the needs of national policy, and the necessity for maintaining the close touch which is necessary between the Advisory Economist and the region he serves, and also for encouraging individual research at all the advisory centres. When the initial difficulties in launching a new and important scheme, such as the Survey of Farm Management, in addition to all the other work being carried on at the advisory centres have been surmounted, it will probably be found necessary to review the staffing and equipment at each centre, to relieve the economists of the merely routine work so that they can give their attention to other problems.

The Institute for Research in Agricultural Economics in addition to sharing in the work of the two schemes referred to above, has carried on investigations on the lines described in previous Reports and has initiated other studies. " The Agricultural Register " is an indispensable annual reference book for those who wish to keep themselves informed about agricultural legislation, trade regulations, administrative measures, supplies and prices of products and requisites, agricultural statistics, wages and employment. By means of annual supplements the quantitative study of the effects of recent legislation upon the sources of supply of Great Britain's food imports, which was published in 1935 under the title " The Planning of Britain's Food Imports ", is kept up to date. A good deal of attention has been given to milk production and consumption studies. Miss R. L. Cohen completed and published a very comprehensive and detailed study of " The History of Milk Prices " tracing the causes which led to the disorganisation which threatened the industry, and the steps taken under the marketing schemes to avert the collapse, with some preliminary discussion of the results of the scheme. Other studies dealt with the costs of re-organisation for the production of tuberculin tested milk, and changes in the utilization of milk due to the setting up of the Milk Marketing Board and the pooling of prices. On the consumption side a survey of 600 households in Oxford during the summer of 1936 was undertaken by Mr. K. A. H. Murray and the results published. While it confirmed the results of other investigations that consumption of milk varies generally with income levels, it stressed the influence of other causes of the low standard of milk consumption in this country such as antipathy, indifference and prejudice, and showed that other factors besides prices had to be considered if consumption was to be increased. The Institute has continued its interest in power farming and agricultural engineering problems. These studies cover the cost of mechanised corn growing, the cost of tractor work, and the cost of grass drying.

The investigation and research work carried on at the advisory centres has shown little change during the two years under review, most of the centres having found the Milk Costings and Farm Management schemes as much as they could manage in addition to work already in hand. At most of the centres there are still one or two cost accounts carried, but it is clear now that this method of securing economic data is likely to diminish.

The financial account still holds first place as the basis of advisory work on farm management, and at the Aberystwyth, Bristol, Midland College, Reading and Seale Hayne centres the numbers of accounts kept are fully maintained. Leeds changed over from a system of modified costings to the financial account system in 1937 and proposes to develop it alongside the Farm Management Scheme.

In enterprise studies milk, poultry and pigs are most in evidence. At several centres studies in milk production were being pursued before the Milk Costings Scheme was formulated. At some centres the work was merged in the larger scheme, but at others the material collected for the Costings Scheme is being submitted to further analysis or independent inquiries are being carried on. Poultry investigations have been made at Aberystwyth, Newcastle, Bristol, Harper Adams, Leeds and Wye. The reports of these investigations make it clear that while disease is a big factor in causing the critical position of the poultry industry, there are other factors in poultry management responsible for the situation. Nor does it appear that the rising costs of feeding-stuffs up to 1936-7, compared to the price of eggs, was sufficient to account for the abandonment of poultry production, particularly in the areas where the poultry population was densest. A study of "Egg Prices" by Mr. O. J. Beilby of the Oxford Institute, along with the reports of the poultry investigations at the different centres, shows the necessity for continued economic studies of farming enterprises if a factual basis is to be found for public policy.

The experience of the Bacon Marketing Schemes has been more educative than encouraging, and has shown that our knowledge of the problems of pig production was considerably less than our confidence in our ability to devise schemes. There is more attention now being given to the problems of management, and investigations are being carried out at Bristol, Cambridge, Seale Hayne and Wye. A Committee of the Conference of Advisory Economists has been set up to consider the development of investigations into the economy of pig keeping and how far the data collected on these investigations can be made comparable.

Mention may be made here of some of the other types of studies being made at the advisory centres. The list is meant to be illustrative, not exhaustive. At Aberystwyth there has always been a keen interest in consumption studies, and this has produced some interesting information about the relation of unemployment to the purchase of food-stuffs. This centre is especially interested in the economics of co-operative marketing and acts as adviser to the agricultural co-operative societies in Wales. Bristol carried out a survey of the market garden area around Evesham: at Harper Adams a study of egg consumption in a town in the region was completed: Leeds has commenced an investigation of beef production: Manchester has concentrated on the economics of grassland with special reference to milk production: the Midland College centre published the results of an inquiry into sand-land farming in the Sherwood Forest area: Reading completed surveys of statutory small holdings and of the agriculture and land utilization of Bucks: Wye College reported on financial problems of sheep husbandry, and completed the fifth year of an investigation into the production of peas for canning. Cambridge, which has for the past eight years concentrated on farm management surveys, issued a series of reports dealing with certain aspects of farming in the Eastern Counties and the adjustments being made to meet the changing market, as shown from the data in the surveys.

Finally mention should be made of a volume entitled "Regional Types of British Agriculture", the work of the Advisory Economists of Great Britain, which was prepared for the International Conference of Agricultural Economists held at St. Andrews in the autumn of 1936. In this volume the main systems of farming to be found in every part of Great Britain are briefly described.

In Scotland there are three Advisory Economists attached to the three Agricultural Colleges and an Advisory Officer in Farm Economics to the Department of Agriculture. In our last Report we recommended that the policy should be to strengthen the work at the Colleges, and an improvement in this direction has been made during the period under review.

A joint scheme in which the Scottish Advisory Economists co-operate with the Advisory Officer of the Department has been in existence since 1928. The Advisory Economists collect financial accounts from farmers within their area, which they use as a basis for advisory work on farm management, but the figures are also tabulated and analysed by the Department's Advisory Officer and issued as a " Report on the Profitableness of Farming in Scotland ". Beginning with 130 farms for the year 1928-9, the eighth Report for the year 1935-6 showed that the number of farms for which accounts were prepared was 296, which shows the growing interest on the part of the farmers and the success of the Advisory Economists in extending their contacts. With the increase in the total number of farm accounts. there is an increase in the number for which accounts have been kept over more than one year and so more direct comparisons can be made and a better indication of the trends secured. As the numbers increase in each of the groups into which the records are divided the data are likely to be more significant, while further groupings may be possible. In the latest report a group of dairy smallholdings in the South-East has been added.

An investigation into the costs of Milk Production in Scotland similar to the scheme adopted in England and Wales was begun, but was brought to a conclusion in the North in 1936 and in the East and South-West in 1937, the Milk Marketing Boards (there are three in Scotland) having withdrawn the support they were giving to the scheme. It is unfortunate that the Milk Marketing Boards in Scotland have not shown the same willingness as the English Board to encourage research into the economic problems of milk production.

The Scottish Advisory Economists have usually other studies in hand in addition to the work in which they co-operate. In the South-East special attention is being given to the economics of small holdings, and to poultry problems and pig keeping in the North and South-West. An interesting development has been the commencement of a mimeographed quarterly entitled " Farm Economics " which is issued by the Department of Agriculture for Scotland to which the Economists contribute bulletins on various aspects of the work in which they are engaged.

III.—SOILS AND PLANT NUTRITION

The soil, broadly speaking, may be studied either in its relation to plant growth or as a natural object in itself. With the study of the soil as a medium in which plants grow and of its enrichment with or deficiency in plant nutrients much of the work of the agricultural research institutes dealing with crop production is concerned; the study of the soil in itself is a younger development and pedology has not until comparatively recently been a subject of concentrated investigation in any one of the research institutes in Great Britain. Of the two major institutes for soil research, Rothamsted has for long years investigated the bearing of soil conditions on plant growth, while the Macaulay Institute, founded in 1930, has a trend towards the study of the soil in itself; naturally, this distinction between the character of the work in the two institutions is not sharply defined.

Rothamsted Experimental Station.

A report on the work in progress at Rothamsted, based on visits by several Sub-Committees which considered different aspects of the work of the station, was received and adopted by the Agricultural Research Council in April, 1936. Rothamsted is the largest of the experiment stations, with a staff of some 50 scientific workers and a grant sanctioned from the Development Fund of £27,755 in 1936-7, apart from a separate grant of £2,440 for plant virus research, special grants from the Ministry of Agriculture and Fisheries for poultry manure experiments and potato wart disease tests, and substantial receipts from other sources. Work bearing mainly on soil problems is organised in departments of chemistry, physics, microbiology, bacteriology and fermentation. The work of the departments of botany, entomology, plant pathology and insecticides and fungicides is dealt with elsewhere in this Report, while the statistical department has interests in every branch of the station's activities, and the plant physiologists of the field experiments department link up with the staff of the Institute of Plant Physiology of the Imperial College of Science and Technology stationed at Rothamsted.

The chemical and physical work on soils covers studies of the plant nutrients in the soil, its water supply and the relations of this to the water requirements of the plant, the physical factors concerned in soil tilth, the characteristics of different soil types and those of particular fractions such as the clay, and the like. Much work has been done on the analysis of the chemical aspects of soil fertility and the relationship of soil analysis to fertiliser requirements. The inorganic and organic soil constituents and soil nitrogen are studied and much effort has been given to the improvement of methods of analysis and of field experimentation. Extensive work is in progress on the nitrogen cycle in grassland and the effect of nitrogenous and phosphatic fertilisers on pastures, the latter in connection with the Basic Slag Committee of the Ministry of Agriculture and Fisheries from whom a special grant is received.

Grassland work at Rothamsted deals with soil and manurial aspects of grassland management and the influence of these and other factors on the composition of the sward. Some of the plots have been under continuous observation for a great number of years, others are laid down for shorter term observation. In Dr. E. M. Crowther's chemical department, Dr. H. L. Richardson has systematically studied the soil nitrogen in the older grass plots where, in contrast to arable land, he found the ammonia always higher than the nitrate, though both were low and this low equilibrium was rapidly re-established even when nitrogeneous fertilisers were added. Seasonal fluctuations were found to be small, though the mineral nitrogen rises in late autumn and falls in the late spring and summer. Annual experiments on the use of nitrogenous fertilisers showed that winter applications were less effective than those in the spring. Under repeated cutting the added nitrogen disappeared from the soil very rapidly and the response in herbage was exhausted in one or two cuts. There is considerable evidence in favour of the view that herbage takes up ammonia directly from the soil. Dr. Crowther's work on the effects of phosphatic manures on grassland has included tests of high, low and medium soluble basic slag, superphosphate and mineral phosphate on a wide range of conditions of soil fertility obtained by trials in various parts of the country as well as at Rothamsted, where some of the work is done in pot cultures. In judging the effect, a reliable and consistent result can be obtained when the yield determinations are supplemented by determining the amount of phosphate taken up by the crop. Superphosphate gave the highest percentage recovery of the added phosphoric acid in the crop in the first year, and high soluble slag in the second, but in general over the first few years the two were similar. Low soluble slag was inferior. On acid soils mineral phosphate was as effective as the superphosphate and high soluble slag, but was below even low soluble slag in neutral soils. In the pot culture work, repeatedly cut perennial ryegrass was used and it was found that the total dry weight and total phosphoric acid uptake followed the citric acid solubility of the slags, only the more highly soluble slags having an appreciable effect. In similar work on turnips in 1936, evidence was obtained that cultivated crops may differ widely in their abiiity to use soil and fertiliser phosphorus. The grasses can make better use of soil phosphates than turnips, which seem to be particularly dependent on phosphorus added in the fertiliser. The broad result of all the work done so far under the Basic Slag Committee is to establish the superiority of high soluble slag, the production of which will thus be stimulated.

Work on the fertiliser requirements of sugar beet includes a number of experiments with various rates of application of sulphate of ammonia, superphosphate and muriate of potash in all combinations. The soils are analysed and an attempt is being made to determine how far the sugar beet crop uses subsoil nutrients. The trials are extended to crops grown in various factory areas and have been supported by special grants from the Beet Sugar Corporation and the National Farmers' Union. The preliminary results show a considerable variation in response to the fertilisers in different years, dry summers having so far given a low proportion of clear cut responses to phosphoric acid and potash. In the wet season of 1936 the response to a single application of nitrogen (2 cwt. sulphate of ammonia per acre) was on the average in weight of sugar nearly four times as great as the average response in the three preceding dry seasons. The experiments also indicate the importance of preserving a proper balance between nitrogen and potash in manuring sugar beet, the response in sugar content being better when both were present than when either was absent, independently of the season.

Similar trials on a smaller scale are in progress on potatoes.

Much work is in progress on determining the forms in which phosphorus occurs in the soil and the relation they bear to the response of crops to phosphates. In many soils added phosphates rapidly become unavailable to plants and this may be due to several different kinds of fixation. Studies on the differentiation of these forms are in progress in the laboratory and field; the fractionation of the soil phosphorus may also assist in the interpretation of soil formation. Work is also being continued on the base exchange properties of the soil and the part played by magnesium in fertilisers and limestones. Manganese deficiency is associated with the " grey leaf " or " grey speck " disease of oats and it may be that the available supplies of manganese in the soil are altered (possibly by the activity of micro-organisms) so as to be made unavailable to the plant. The clay fractions, inorganic soil colloids, are under study as regards their structure and properties.

Work on the organic soil constituents is also in progress in the chemical department, especially as linked with the conversion of the organic nitrogen compounds into forms of nitrogen available to the plant and with changes in the physical properties of the soil resulting from the application of organic manures. Methods for determining the rates of decomposition of organic manures are being tested, and in the biochemical section the contribution made by the different plant constituents which undergo decomposition in forming humus is being studied.

In view of the shortage of farmyard manure on modern mechanised farms, methods of increasing the supply of organic material to the soil are being examined. The use of straw for this purpose is being tested against farmyard manure in various ways, e.g., by rotting the straw in heaps with the necessary addition of nutrients for the straw-decomposing micro-organisms and by direct ploughing in of the straw and the addition, either with the straw or at a later date, of artificial fertilisers. The effects are compared both in the year of application and in the four succeeding years of a four-course rotation. So far, the response has been marked for the first two years but is less evident in the third. The straw gave the best results, except on potatoes, in which the dung was best. A three-course rotation experiment on the same lines was completed for three years in 1936, the tests also including a series with artificials only. In the year following application the non-fermented straw was better than the artificials. The changes in the nitrate, ammonia and oxidisable organic matter in arable soil after green manuring and ploughed in leys are also being followed.

On the physical side Dr. B. A. Keen and his staff are studying the water relations of the soil and the effects of soil tilth. Earlier work both on heavy soil at Rothamsted and on light land at Woburn gave little support to the idea that yields are greatly dependent on cultivation and led to critical examination of the traditional beliefs regarding the value of particular cultivations. The present experiments fall into two main groups: an examination of the effects of standard operations varying from subsoiling to rolling, and a comparison of standard methods with rotary cultivation. In securing tilth the essential point is to bring the soil into an aggregation of crumbs and prevent it from falling into dust. Crumbs that persist when moist give more productive soils than those which readily break down. Stability is greater for a calcium clay and is increased by some kinds of micro-organic action. The actual changes depend on the drying and re-wetting of the soil and are brought about largely by the weather, but the implements put the soil into conditions in which the weather can act. Studies are in progress on the effect of meteorological conditions on the size distribution and degree of permanence of soil crumbs and also on the influence of the amount of organic matter present in the soil. The introduction of rotary cultivation led to the need for comparative tests, against traditional methods, of the effects of this form of cultivation to varying depths and taking into account any cumulative action.

In the tests of standard operations the results from an extensive series of inter-row cultivation experiments have been to show that stirring the land beyond the minimum required to keep down weeds and to prevent " capping " on soils where this is prone to occur is useless labour at the best and may even reduce crop yields. In ploughing no apparent advantage has been obtained in going to a depth greater than four inches for cereals, but for mangolds a depth of eight inches is advantageous. Ploughing and harrowing prepare a seed bed as well as, and often better than, the use of cultivators, but if time is important ploughing may be dispensed with for one year and cultivators used with little detriment to the yield, especially if they are worked deeper than four inches. Rotary cultivation is not as effective as the standard methods of ploughing and harrowing, whether for roots or cereals, but is better than the cultivator alone. In comparative tests no harmful effects from using the Rototiller year after year have been observed provided it is worked to about eight inches depth for mangolds. Rotary cultivation, however, appears to encourage those kinds of weeds that grow from fragments.

The important studies on water relationships of the soil have been continued. They have led to the abandonment of the old capillary-tube theory of water movement in soil; the pore space is regarded as a series of cells, communicating with one another by narrow necks. These cells and passages are formed by the aggregation of the soil into crumbs. When filled with water, as after rain, they hold much of the moisture and only the surplus drains away to the water table. Conversely, in drying, the top layers first dry, then those next below and so on. There is little upward movement of water from below. The water held by the soil is relatively static and resists movement. The conclusions as to the results of cultivation mentioned above are in harmony with these views, the effect of cultivation on the moisture relations of the soil being much less than would be expected under the capillary theory of water movement.

When plant roots take up water from the soil the same considerations apply. Depletion of water around the root is local and only slowly extends farther out. Different soils possess varying powers of holding water against the pull of the root and the resistance to the pull varies accordingly as the soil is becoming wetter or is drying out. The scale evolved by Dr. R. K. Schofield for giving a quantitative value to this pull at different points, e.g., when the plant begins to wilt, when its water supply is optimum, etc., was mentioned in the last Report.

The effect on the soil of this root action in extracting water is important. Under conditions such as at Rothamsted the drainage through cropped soil is only about one-half that through uncropped soil. The marked differences between feebly and strongly podsolised soils are largely due to the intensity of action of the roots in removing soil water. Certain elements such as calcium, potassium, silica, etc., are lifted in quantity with the water from the subsoil to the above-ground parts of the plant and returned to the top layers of the soil when the plant withers. This counteracts the washing down by the rainfall, and in mild humid climates the upper layer tends to be richer in calcium and potassium than those deeper down.

An attempt is being made by physical methods to provide broad grouping between physical properties, soil type and inherent fertility. Extensive physical studies of different types of clay are in progress. Work on the plastic behaviour of soil pastes was extended to flour dough as a suitable substance for such studies, and proved of importance to the milling and baking industries. The work with flour has thrown light on the structure of plastic substances in general and has assisted in the study of the micro-plastic movements of soil aggregates in relation to the typical crumb formation of a soil in good tilth.

In the general microbiological department, Mr. D. Ward Cutler and his staff are engaged in studies of the protozoal and bacterial population of the soil. This population has been found to be much denser than was at one time realised. A gram of field soil may contain several thousand million bacteria, with millions of actinomycetes and fungi and many thousands of protozoa. Methods of calculating their numbers have been vastly improved. Studies are in progress on the balance of the population of soil-inhabiting organisms and the disturbances in this balance caused by various agricultural practices, manurial treatments and the like. There appears to be little connection between the geological formation of the soil and its protozoal population except in peats and blown sand, but the heavy soil of Rothamsted and the light soil of Woburn support bacteria differing widely in some of their characters. Thus, among the nitrogen fixing organisms, *Azotobacter* is absent at Woburn but dominant at Rothamsted. Fungi and actinomycetes have been found at Rothamsted to be more numerous and varied in fertile than in poor soils, and to be somewhat fewer in winter than in summer. Certain species of fungi increase in relative proportion in soil under continuous cultivation of certain crops, such as mangolds. Studies are in progress on the soil organisms responsible for the various stages of nitrification in Rothamsted soils, and bacteria in pure culture are being used for work on nitrate reduction, especially with a view to determining the effect of such factors as the carbon-nitrogen ratio on the process of denitrification. Further work is being carried out on certain bacterial strains which produce nitrogen gas from nitrate under aerobic conditions.

The respiration of bacteria has been under study in this Department for several years, the oxygen uptake of cultures of a single strain of bacteria under different conditions and of different strains under similar conditions being determined. The method of measuring the oxygen uptake has been applied, in a study in collaboration with Dr. J. Caldwell, to determine the differences in metabolism between virus diseased and healthy plant tissues.

In conjunction with the Fermentation Department an investigation has been carried out for the Department of Scientific and Industrial Research, with grants received from that Department, on the purification of milk effluents. The bacteria isolated from septic tanks and filter beds used for treating milk are not similar to those ordinarily occurring in the soil. Anaerobic conditions of fermentation cause separation of most of the fat, the presence of which in milk effluents leads to clogging of the filters. The separated liquid can then be subjected to biological oxidation on percolating filters to yield an inoffensive effluent. Purification can also be effected by the activated sludge process. Factory scale plants for both of these processes have been established.

The purification of milk effluents largely arose from the work of Mr. E. H. Richards and his colleagues in the Fermentation Department at Rothamsted on the purification of sugar beet factory effluents, work which has shown that purification can be operated on a large scale at factories to produce an effluent purified to the extent of about 90 per cent. Much of the work of this Department during the period under review has been directed to the investigation of the changes which organic manure undergoes in the process of decomposition under aerobic and anaerobic conditions. The losses of the various plant constituents, celluloses, lignin and the like, and the production of organic acids, amines and gases are being determined for anaerobic decomposition under different conditions of temperature, moisture, available nitrogen, etc. Working in conjunction with this Department Dr. A. G. Norman has carried out studies of aerobic biological decomposition of plant materials. These have involved intensive studies of the celluloses and other components of the plant cell wall and of the methods of their analysis. Dr. Norman has also worked in collaboration with Dr. D. J. Watson on the composition of crop plants in respect of such substances as the hemicelluloses and the like at different stages of development. Other work in this field included studies by Mr. C. N. Acharya of the decomposition of rice straw under conditions such as those found in the rice fields of India, where the micro-organisms act in the presence of only a small amount of air. Under these conditions the concentration of nitrogen requirement for decomposition was low.

A great part of the work of the Bacteriology Department under Dr. H. G. Thornton has been directed in recent years to the relation between the nodule organism and the leguminous plant with which it is normally associated. The important discovery that clover grown in hill pastures, as in Wales, becomes infected with wild strains of the clover nodule organism that not only produce ineffective nodules but are capable of competing against the better strains where these are present has led to a search for effective strains that would withstand this competition. Some of these have been found and are being tested, while the reason why the wild strains can prevent the formation of good nodules is being investigated; the competition between the good and poor strains is being studied both outside the plant and after infection of the root. As it has already been shown that successful competition can be a property of strains that are effective nodule formers and active nitrogen fixers, there is good promise that clovers can be inoculated with strains of value in localities where the existing strains are normally ineffective.

Nitrogenous manuring has been shown to hinder the development of nodules and this deleterious effect is accentuated in mixed legume-grass associations such as are commonly found in clover pastures, for the fertiliser promotes an excessive growth of the grasses relatively to the clovers.

The details of the process of infection of the root by the nodule organism have been followed. Infection through the root hairs is preceded by a curling of the hair, which is not caused by the presence around the hair of other bacteria. Entry into the hair is effected by the bacteria at the interior side of the curl. A polysaccharide which produces this curling effect has been extracted from the nodule bacteria.

Work on the fluctuations in the numbers of bacteria in the soil indicates that these fluctuate even in soil kept under constant conditions of moisture and temperature, suggesting the existence of some cyclical change in the numbers. Work on soil bacteriophages is also in progress.

The Macaulay Institute for Soil Research.

This Institute is situated at Craigiebuckler, on the outskirts of Aberdeen. Its Governing Body includes representatives of the Department of Agriculture, the University of Aberdeen and the three Scottish Colleges of Agriculture, and close contact is maintained with the University and the North of Scotland Agricultural College.

The grant sanctioned from the Development Fund to the Institute for the year ended 31st March, 1937, was £5,984 and that for the year 1937-38 was £6,934, apart from some additional sums for capital expenditure. There are, in addition to the Director, Dr. W. G. Ogg, six scientific members on the staff, besides a temporary worker engaged in connexion with a scheme of peat land reclamation which is being carried out in Lanarkshire for the Commissioner for Special Areas in Scotland under the grant for this scheme. In addition, the Institute is responsible for the management of the Macaulay Farm in the Island of Lewis where various problems in the improvement of poor peat land are being studied.

The work of the Institute is divided into sections dealing respectively with soil surveys, geology, general soil fertility and advisory work, peat investigations, forest soil investigations, lysimeter studies and spectographic analysis. The Director, Dr. A. Muir and Dr. R. Hart are engaged in soil survey work and the geological and mineralogical study of soils and subsoils with special reference to their origin. The soil survey work will be referred to below (p. 55). Dr. Hart's studies of the mineral content of soils have been concerned chiefly with those of the north-east of Scotland, where the minerals can be separated into three groups, quartz, felspars, and ferromagnesian minerals and iron oxides; the presence or absence of minerals containing plant nutrients, as potassium, phosphorus and calcium are noted. The mineral constituents in the sand fractions are determined, as well as their state of freshness and their weathering products. The soils are grouped on the results of these examinations and their relation to the parent material studied. The work has been extended to the finer fractions of the soils, the silts and particularly the clay complex. In the glacial drifts of Kincardineshire, where much of this survey has been done, the drift is very complicated and derived from a variety of rock types.

The soil fertility work of Dr. A. B. Stewart is carried out in the field and in pot experiments. In the latter a series of soils typical of many of those common in Scotland is maintained in Mitscherlich pots after detailed chemical and mechanical analyses, and their response to artificial manures noted each season. This work furnishes a basis for the extensive advisory services rendered by the Institute to farmers. The bulk of the advice is connected with the manurial and lime requirements of the soils concerned, and the laboratory analysis of the soil is supplemented by reference to the response of the particular soil type to manures in the pot cultures. Especially in connexion with the estimation of available potash it was felt at the meeting of sections of the International Society of Soil Science, held at the instigation of Professor Mitscherlich at Königsburg in July, 1936, that further examination of methods was required. Dr. Stewart arranged to co-operate in this work by examining samples of soil from selected centres in Scotland by field methods, by the Mitscherlich pot method and by various chemical methods, similar samples of the same soils being sent to other workers to study the effects of different climatic conditions on the results. Reciprocally, certain samples from abroad will be studied at the Macaulay Institute.

In Dr. Stewart's field experiments soil type, subsoil effect, volume weight, cropping, etc., are taken into account. Experiments are in progress on the Craibstone Farm of the North of Scotland Agricultural College in collaboration with the College, and at a large number of centres in various parts of the country, on soils, selected samples of which are also examined in the laboratory and tested in pot cultures at the Institute. Particular attention is being paid to the relative effects of superphosphate, basic slag, ground mineral phosphate and steamed bone flour on crop yields and on soil properties. In 1937 the Agricultural Research Council gave their support to the appointment of an assistant to aid in the advisory work of the Institute, which has grown to considerable proportions.

The special work on peat soils was in charge of Dr. I. M. Robertson until 1936, when he was appointed to the staff of the Edinburgh and East of Scotland College of Agriculture. He has been succeeded at the Institute by Dr. G. K. Fraser. The work is closely linked with that of Dr. Stewart, in that it is largely directed to furnish a basis for advisory work in regard to the drainage, cultivation, liming and manuring of the soil, in this case of peat soils. The methods of examination differ in peats from those applicable to ordinary soils, but field and pot culture experiments are carried out. The Institute is responsible for the scientific direction of two major reclamation projects, that for which the Macaulay Farm in the island of Lewis serves as a centre and that in Lanarkshire financed by the Commissioner for Special Areas, on which Dr. L. A. Whelan is temporarily engaged. The peats differ in the two areas, the Lewis peat being colloidal and difficult to drain while that in Lanarkshire is fibrous. Work on the former has proved exceptionally difficult and by the end of the financial year 1935-6 the accumulated debt was £1,951, much of which represented capital expenditure, while in September, 1937, the sum required to extinguish debt was £2,607. Grants towards the cost of running the Farm have been made from the Congested Districts Fund on the Vote of the Department of Agriculture; £600 was thus provided in 1936. In November, 1936, the Agricultural Research Council arranged a conference with representatives of the Department to discuss the future of the work of the Macaulay Farm and the financial position of the Farm. In establishing the farm, the donor, Mr. J. B. Macaulay, had in view not only the study of the agricultural development of moorland and the provision of information to enable crofters to carry out reclamation and land improvements but also the promotion of agricultural research into problems not dealt with elsewhere. The Council recommended that the maintenance of the Farm should be considered separately from that of the Institute, but that if established on a sound economic basis there would be scope for valuable investigations on its biochemical and other problems in conjunction with the

Institute. If the demonstrational reclamation work, with which the Council were not concerned, could be maintained, the Council would be prepared to recommend the provision of special research funds to enable the Macaulay Institute to extend its research work into the peat problems arising at the Farm. Some of these bear directly on the methods of reclamation, which may be capable of improvement in the direction of shortening the period of preliminary treatment before a pasture can be established; others include microbiological and biochemical work, which would be directed to a study of the causes of the effects produced in peat by liming and fertilising and the changes occurring in rendering the peat fertile. Proposals for placing the finances of the Farm on a more satisfactory footing are understood to have been approved.

Work on forest soils carried out at the Institute is supported by an annual grant from the Forestry Commission (£600 in 1936-7) and is outside the scope of this Report. It has many points of contact with the soil survey and peat investigations in the main body of the Institute's work.

Mr. H. D. Welsh is engaged on the examination of soil drainage water carried out in lysimeters at Craibstone and has collaborated in the application of spectrographic methods to the analysis of the drainage waters. The lysimeters were constructed by Professor Hendrick and were used by Mr. Welsh before the Institute was founded; each has a surface area of one thousandth of an acre and encloses a block of soil 40 inches deep. Crops are grown in rotation, those on one lysimeter receiving no manure, while the others get manures, and lime with manures, respectively. The most interesting result has probably been the small amount of nitrates leached through the cropped soils. Apparently, in the presence of a crop, the soil loses little nitrogen through drainage under the conditions prevailing at Craibstone. Losses in phosphates and potash have also been low, but that of calcium considerable. This is in support of other evidence showing the importance of lime in these soils. The more heavily the soil is manured with the ordinary artificials the greater is the loss of lime from it. Mr. Welsh is also responsible for much of the analytical work of the Institute.

A special research grant of £850 was made from the funds at the disposal of the Agricultural Research Council during the financial year 1935-6 to provide for the development (including the purchase of the necessary equipment) at the Macaulay Institute of the methods of spectrographic analysis of soils devised by Professor Lundegärdh in Sweden. Dr. R. L. Mitchell was appointed for this work. After a preliminary period of study of the spectrographic methods in use at the Government Laboratory in London and a visit to Professor Lundegärdh at Stockholm to study the technique evolved by him for soil studies, work with the new apparatus was commenced at Aberdeen in October, 1935. The exchangeable bases removed from the soil by leaching with ammonium acetate were first examined, together with determinations of the available potash as extracted by dilute acetic acid. The method involves the photographing of the spectrum emitted when a spray of solution containing certain cations is injected into an air-acetylene flame. The intensity of the spectrum lines so obtained is measured photo-electrically and the actual amount of the element present in the solution is determined by reference to the spectra of standard solutions. The cations so determined in the earlier work were calcium, magnesium, strontium, potassium, sodium and manganese, and their distribution in the various layers of numerous soil profiles was studied. The results were checked against chemical determinations by analytical methods of the elements in the same soil solutions, and the agreement found in the routine work, normally duplicate determinations, was about ± 4 per cent. In this early work it was found that about 16 such extracts could be analysed for the exchangeable bases in two days at a cost for the six elements mentioned of 7s. 6d., or just under one penny per determination. The estimation of the available potash costs more, about threepence per determination, and takes about four hours for 16 determinations. Other early work included the examination of drainage waters, including those from the Craibstone lysimeters, determinations of total alkali and alkaline earth contents, and a study of the amounts of manganese removed by dilute hydrochloric acid from the same profiles in which the exchangeable bases were estimated, in order to gain information of the " gleying " of soils. A series of spectrographic ash analyses for potassium, calcium and magnesium was carried out with samples of grass from differently fertilised pastures.

In 1936-7 the special grant for spectrographic work was renewed at the rate of £350, of which £50 was to provide additional equipment to allow of the spectrographic determinations being extended to certain other elements. Some of the minor elements, whose availability to plants and animals has been shown by recent research to be a matter of some importance do not give flame spectra, but can be identified in a spark spectrum. Amongst these are boron, molybdenum and arsenic, while cobalt, nickel and chromium are seldom present in such amounts as to be observed satisfactorily in flame spectra. Boron deficiency is the cause of certain plant disease, and cobalt appears to be of significance in some animal troubles, such as " pining " in sheep. With the new equipment the determination of elements ordinarily present in small quantities in the soil, including boron, cobalt, copper and zinc, has been undertaken and various artificial fertilisers are being examined for their boron, cobalt and manganese content. Data have been obtained on the relative rates of movement in soil profiles of the six exchangeable bases studied in the earlier work and studies are also in progress on the movements in the soil, during the processes of soil development, of elements other than those usually studied.

It was early noted that the aluminium content of hydrochloric acid soil extracts had a disturbing influence on the determination of the sensitive alkaline earths, and further examination showed that even small aluminium contents of the order of 1 mg. per litre may affect the determination of calcium and strontium. It was found, however, that by adding sufficient strontium to the solution in which calcium is to be determined there is no depression of the apparent calcium content, while in soil extracts the strontium can be determined directly, as there is always sufficient calcium present to counteract the effect of aluminium on the strontium.

Since the beginning of the financial year 1937-8 the expenditure on spectrographic work has been transferred to the block grant of the Institute. The results of this work have proved to be most interesting and useful in experienced hands. Though the method is being used primarily for research purposes, a certain amount of the routine analyses are already being done by it. Several of the enquiries mentioned above have been carried out in conjunction with other members of the Institute's staff.

Long Ashton Research Station.

The Agricultural and Horticultural Research Station of the University of Bristol at Long Ashton was visited by a Sub-Committee appointed by the Plants and Soils Committees of the Agricultural Research Council, whose Report on the work of the Station was adopted by the Council in November, 1936.

Most of the work dealt with is reviewed in a later section of this Report (p. 98), but the important investigation on soils and plant nutrition call for mention here.

The district surrounding Long Ashton, like the site of the Station itself, provides a wide range of variation in natural conditions—geological structure, topography and climate. In the years 1913-20 a good deal of attention was given to the manurial needs of fruit crops by the late Mr. Lees, and soon after Dr. T. Wallace joined the staff he began systematic surveys of soils in several counties. Assisted by Dr. D. A. Osmond, this work has gone on continuously, with the result that the special characters of the more important fruit growing soils of the Province are now well known and correlations between soil series and tree growth have been established. Further reference to this work will be made in the section on Soil Surveys below (p. 55). Observations made in the course of this survey were followed up in the laboratory; systematic manurial trials were laid out on selected plantations in adjacent counties, and a wide " clinical " experience has been acquired, so that from the appearance of unthrifty plants inferences as to the probable soil deficiencies can now be made. At an early stage pot experiments on artificial soils and in pure sand were begun, and through the Empire Marketing Board a large plant house was provided so that trees might be grown under controlled conditions.

The work in progress in this Pot Culture Station was demonstrated to the Sub-Committee by Dr. Wallace. Having determined through sand cultures, suitably enriched, the effects of deficiencies in various mineral nutrients, such as potassium, magnesium and calcium, and of different mineral ratios, on tree growth he was studying the relation of nutrition to fruit quality, and at the request of Wisbech Fruit Growers' Association was making a special study of the relation of mineral nutrition and environmental factors to " bitter pit." In connection with the latter subject and in investigations on the influence of cultural conditions on the keeping quality of the fruit the cold store, also provided by the Empire Marketing Board, was being used.

The pot culture work is being linked up with manurial trials made on Long Ashton plantations. As already mentioned the variable character of the Station's soils provides a wide range of suggestive material for study, while, with apples especially, the effect of various mineral deficiencies on trees grown on different stocks can also be determined, the field work being controlled by pot experiments with apples on contrasting types of stocks. In the plantations manurial experiments relate to two main subjects, the elucidation of the differential effects of grassing as against clean cultivation, and the effects of potash deficiency on the growth of a series of fruits—apples, black currants, gooseberries and strawberries. A comprehensive range of apple varieties on Malling No. II stock is grown by the Pomology section of the Station under three systems of cultivation, namely, arable without nitrogenous manuring, grass with 5 cwts. nitrate, and the same with mulching. These plots are used for chemical work in following the cycle of total nitrogen fractions, especially nitrate and ammonia, under arable and grass. This work is linked with that on the nitrogen cycle in the tree, referred to in the section on Plant Physiology (p. 71). Potash deficiency causes a stunted growth and death of the tips of the shoots in apple trees. In the September gales of 1935 all the leaves on the potash-starved trees at Long Ashton first turned brown and subsequently died off. Lack of potash also results in the over-production of fruit buds in apples, the reason for which is obscure and awaits investigation. Black currants and gooseberries, like apples, suffer considerably from a deficiency in potash; the latter are very susceptible to leaf scorch when they get insufficient supplies of this mineral. Red currants appear to suffer readily from potash deficiencies but they respond slowly to applications of potash manures. Manurial experiments on strawberries have been carried on for a number of years on a fertile soil apparently well suited for this crop, but the results have been vitiated by attacks of various diseases; indications of the effects of manures on quality have, however, been obtained. In strawberries, as in other crops, potash deficiency results in leaf scorch, and when phosphates are lacking total failure has been recorded.

The Sub-Committee thought that additional work might with advantage be done on the strawberry. Work on strawberries such as Dr. Wallace has carried out on apples, if properly supported from the entomological, mycological and virus aspects, might go far to solve the present day strawberry problems.

The general manurial programme of the station includes studies of the effects of various fertiliser elements on fruit trees, of the time of application of the fertiliser, and of the relation to manuring of soil conditions and cultural treatment.

Much of the work in progress in this section involves chemical analysis of plant material. The chemical assistant, Mr. J. E. Kench, is wholly employed on this work, in which he assists Dr. Wallace and Dr. E. S. Smyth, whose work is further referred to in the section on Plant Physiology below (p. 71). Chemical work on the soil problems arising in the experimental plots was, however, practically in abeyance at the time of the Sub-Committee's visit for lack of technical assistance. The Agricultural Research Council recommended that a second chemical assistant should be appointed in order that the valuable information available on the Institute's plots should be fully utilised. The Council also recommended the provision of a separate chamber for nitrogen determinations.

East Malling Research Station.

The soil at East Malling, a well drained loam or sandy loam overlying calcareous ragstone of Lower Greensand formation, is generally of fine quality for the purposes of a fruit research station. It has been carefully studied by several workers, including Mr. W. A. Bane, the soil expert at the Station, who started work on fruit soils in 1929.

The effect of different manurial treatment on a variety of fruits is being followed. When the Station was visited by the Sub-Committee, whose report is more fully referred to below (p. 97) plots were seen in which Bramley Seedling apples worked on various Malling stocks had been grown without manuring for 11 years. Stock influence was marked, for the trees on one stock (Type IV) showed little adverse effects while the others exhibited symptoms of starvation when they came into bearing. In the twelfth season the effects of different combinations of nitrogen, phosphorus and potash were tested in this plantation. A sharp improvement followed in the second season after potash manures were applied. Nitrogen proved useful to a much less extent, but in a few cases the addition of nitrogen increased the benefit from potash. In this area no clear advantage resulted from the application of phosphates, though there was some indication that such an application improved the quality of the fruit on certain trees.

A fresh experiment was then undertaken to test thoroughly the effects of the common manures on a soil not only naturally deficient in potash but further exhausted by taking four cereal crops in succession. Four contrasting apple rootstocks were used, with two scions (Cox's Orange and Beauty of Bath) each worked on all four stocks. Randomised plots of all these stock-scion combinations are being treated with nitrogen, phosphorus and potash singly and in combinations and full records of all the effects are taken. Although the trees were young and just coming into bearing at the time of the Sub-Committee's visit, certain results of interest were appearing. A pathological condition characterised by blistering of the bark had become severe on the Cox's trees on Malling IX stock but was slight on stock XII.

The most interesting features of the soil work at the Station centre round Dr. W. A. Roach's spectroscopic studies of the rarer mineral elements, and Mr. W. S. Rogers's observations on root development. Dr. Roach has shown resource and ingenuity in adapting a standard spectroscope, which he has modified so as to serve his particular purpose. The rare elements of which he has to take account include nickel, cobalt, titanium, vanadium, silver, lead, molybdenum and boron. Primarily his study aims at throwing light on stock and scion relationships; there are indications, for example, that molybdenum may be associated with a dwarfing effect and precocity of bearing.

A subject with a wider, and for the present a more immediate practical bearing on which Dr. Roach is engaged is the question of how deficiencies of elements may be made good by direct injection of trees, instead of by the usual method of applying fertilisers to the soil. Injection enables the specific effect of any element to be determined, and can also be used for increasing production on the large scale. Specimens of prunings from trees thus fertilised with a mixture of potassium phosphate and urea at the rate of from 10 to 50 lbs per acre seen by the Sub-Committee during their visit showed a marked increase in growth when injections of sufficient amount (20 lbs. per acre and over) had been used. The method is also used in the diagnosis of mineral deficiencies in the plantations and, as will be described below (p. 70), in the treatment of physiological disorders. As injection work would be called for during part only of the growing season, the Sub-Committee thought that it should be possible for Dr. Roach, assuming adequate technical assistance to be provided, to pursue both this work and that on spectrographic analysis concurrently. The Council's recommendation that an assistant, not necessarily a graded member of the Staff, be appointed to aid Dr. Roach has since been adopted.

Mr. Rogers's studies of root development carried out in pits lined with glass panels are referred to at more length in other sections of this Report (see pp. 71, 106). The method is one which appeared to the Sub-Committee to be capable of giving much information on matters connected with the relations between roots and the soil in which they are growing, about which there is little information. Mr. Rogers is also studying the effect of the soil moisture content on the uptake of water by the roots by means of an apparatus which he has devised for measuring the force against which the root has to pull in order to obtain its moisture from the soil. Thus, in one series of experiments it was found that when the pull required by the plant to obtain moisture from the soil was not more than 30 cms. of mercury no visible wilting of the leaves occurred. At 40 cms. wilting began and between 49 and 55 cms. the plant wilted completely. These quantitative results are valid only for the particular set of conditions under examination, but the apparatus is being used in a grassed-down orchard, in a clean fallow, in a watered plot and in the glazed root pits.

Cheshunt Experimental and Research Station.

The soil work at the Station for glasshouse crops, the general organisation and programme of which are referred to elsewhere (see p. 108), is in the charge of Dr. O. Owen. A considerable increase in the number of samples of soils, waters, etc., received by him has been reported in the last few years, the analyses made in 1936 being more than double those made five years earlier. Besides this routine work, manurial experiments are carried out on the principal crops grown at the station. Use is made for some of these of a series of plots in one of the glasshouses, where different plant nutrients have been omitted for many years from the fertilisers applied to certain of the plots. Lettuce thus grown in 1936 showed that phosphate deficiency allowed of the growth of good heads, but the hearts were less firm and only half the size of those in the plot receiving a complete fertiliser. Nitrogen deficiency gave small loose heads with a tendency to elongation of the stem. In the potash deficient soil the plants were elongated, with crumpled and distorted leaves and very poor hearts; these plants were commercially quite useless. Experiments with lettuce in frames gave good results from the use of a fertiliser consisting of bone meal, hoof and horn, and sulphate of potash and also, though not so good, from bacterised peat without other fertilisers; the most important result, however, was to show the advantage of warming the soil, the plants in soil warmed to 60° F. being by far the best. Extended experiments on soil heating with other crops are in progress, soil temperatures of 55°, 60° and

65° being maintained both in frames and in the open. Two of the tomato glasshouses are also provided with soil warming installations and in these more elaborate experiments, including the progressive raising of the temperature after the two bottom trusses have set, are being carried out. Soil sterilisation by steam, applied in another house, gave yields only slightly in excess of those in soil warmed progressively to 80° F. during growth, but the roots were quite free from eelworm infestation which was present in the warmed soil.

Experiments on the use of peat in tomato soils have resulted in the extended use of peat by commercial growers. It can either be mixed with the top ten inches of the soil or applied as a thin layer to the surface. The latter method has been shown to be of value in promoting surface rooting where the original root system has been weakened.

In connection with the new facilities provided at the Station for the experimental study of mushroom growing (p. 109), Dr. Owen carried out preliminary experiments on the gases evolved in a manure heap during preparation for use in mushroom beds. Ammonia and carbon dioxide are evolved in maximum amounts after each turning of the heap, the former apparently ceasing to be given off after four or five days, while the carbon dioxide falls to half or less in a short time and then remains constant until the next turning. Ammonia seems to be generated only at the surface and not inside the body of the heap.

The Horticultural Research Station, Cambridge.

The objects and constitution of this Station are described elsewhere (p. 78). It was visited in 1936 by a Sub-Committee of the Plants and Soils Committees of the Agricultural Research Council, whose Report was adopted by the Council in November, 1936.

Work on the manurial requirements of vegetables is in the hands of Dr. R. M. Woodman, whose programme was prepared in consultation with the Committee of Management of the Station in 1934. It is two-fold: permanent manurial field plots have been laid down designed to show the effect of missing out in turn the elements nitrogen, phosphorus and potassium; and pot culture experiments have been started in which the response to each element and the deficiency symptoms resulting from scarcity of it are studied. The field plots are 30 in number, each of one-hundredth of an acre, and on them a simple range of N.P.K. combinations, with and without dung, is being tested on Brussels sprouts, peas, summer lettuce, spring cabbage and carrots in a four year rotation. The plots are in triplicate and the rotation was started in 1935 with peas, summer lettuce and sprouts, respectively, on the three series. In 1936, spring cabbage followed by carrots were on one set of plots, summer lettuce on another and peas on the third.

In the pot culture house, erected in 1935 with a small laboratory adjacent, a series of sand cultures were being run with lettuce in which, in comparison with a complete fertiliser, the amount of phosphate was varied from none, up through various degrees of deficiency and excess, to phosphate alone. This work has been extended on similar lines to potash. Other pot culture work was being carried out with root crops, for which a good " control " medium for the sand cultures had been devised, which gave plants against which the effects of varying the proportions of an essential element could be measured. Soil cultures in which successive crops are grown in the same pots, manured on the " triangular " system, were also in progress. Soil cultures proved to be unsuitable for lettuce, work on which has been restricted to the sand cultures.

Dr. Woodman informed the Sub-Committee that he considered that with the limited land and labour at his disposal the simple lay-out of the field plots that he had adopted was the best. An arrangement devised to give more statistically significant results than he could hope to get on the land available was less necessary with permanent plots than where the trials were to last for only a year or two. The crops are harvested in three or four successive harvests in an attempt to find the influence of fertilisers on earliness, and are graded for quality. Some years must elapse before definite results can be expected. He had found that the pot culture work was very complex. The deficiency symptoms resulting from lack of a nutrient can be most satisfactorily studied in pot cultures, but the response of the crop to a particular fertiliser was much more difficult to assess, though here again he thought pot cultures provided the best method of obtaining exact knowledge. One of the difficulties was to find the complete culture medium, possibly varying for each crop, which should be adopted as a control to furnish a standard against which alterations in the amounts of each nutrient could be tested. The main object of the work was to make out an exact ratio of fertilisers for each vegetable crop. In the space at his disposal he could experiment on variations in only one element at a time and two or three years would be required to complete a crop.

The Sub-Committee questioned whether the scale on which Dr. Woodman was working was adequate to give results of value and recommended that further consideration should be given to this branch of the station's work. Since the whole question of the development of research on vegetables and flowers has been taken into consideration by a Joint Committee of the Agricultural Research Council and the Departments of Agriculture, this further consideration has been deferred.

The Welsh Plant Breeding Station, Aberystwyth.

Though work on the influence of manures on ordinary herbage is carried out at this Station, its most important work in this connection is that relating to the improvement of rough grazings and poor hill pastures. Critical work on open hill pastures was begun in 1927 with a series of controlled manurial trials in fenced plots. The work was done with the co-operation of Professor T. W. Fagan of the Agricultural Chemistry Department of the University College of Wales. The results have shown a remarkable response to a complete fertiliser with a heavy addition of lime, the yield being three times that of the control plots and the response much greater than in similar experiments on lowland pastures. Lime alone gave a very good response in adequate quantities; nitro-chalk alone was practically without influence, but when combined with phosphates (as basic slag) the response was very marked, considerably exceeding expectations. The average yield from a large number of plots receiving this last combination was 325, when the yield from the control plots was taken as 100.

Probably more important than the increase in yield in these poor pastures brought about by manuring is the change effected in the botanical composition of the herbage, especially when supported by heavy and controlled grazing. Early experiments showed that *Molinia* (which, with *Nardus,* is responsible for much almost worthless grassland) could be reduced from 60 per cent. of the herbage to 15 per cent. by manuring with phosphates and nitro-chalk when hard grazed.

Much work has also been done on manuring for seed production. The manurial requirements for optimum seed production are by no means the same in all grasses. On most grasses nitrogen stimulates the production of seed, but this is not the case in the fescues. Nitrogen also causes timothy to mature earlier. Phosphates and potash appear to be of less value in suitable land for seed growing, except with perennial ryegrass.

School of Rural Economy, Oxford.

The Soil Science Laboratory at Oxford, under Mr. C. G. T. Morison, is engaged mainly in a comparative study of the soils not merely of the British Isles, but also of the more important climatic types of soil which occur in other parts of the world and the relationship of the British types to these. A considerable collection of soil monoliths representative of the great world groups has been assembled at the Laboratory with a view to facilitating these comparative studies. Work of a more intensive nature has been done on specific groups of local soils in order to ascertain the nature of the soil vegetation unit and to determine, if possible, the place of the soils in question in relation to the great climatic groups. Towards this work, on which Mr. G. R. Clarke is engaged, an annual grant of £50 is made from the Ministry of Agriculture and Fisheries, charged on the Development Fund.

In 1935 the Agricultural Research Council made a grant to the School of Rural Economy of £300 for one year to initiate an investigation into the changes which take place in clay particles during dehydration, to be carried out under Mr. Morison's supervision. Dr. J. R. Russell was appointed to undertake the work, with effect from the 1st October, 1935. The grant was renewed at the same rate for the year from the 1st October, 1936. Dr. Russell carried out experiments on methods of purifying and dispersing clays by electro-dialysis, avoiding as far as possible any chemical treatment which might be severe enough to alter the chemical properties of the clay surface or to cause flocculation, and also by leaching. A satisfactory leaching and filtering technique was evolved. The separation of different constituents of the clay by means of fractional coagulation or peptization was then carried out. The early results indicated that at least two different constituents with sharply differing colloidal properties are normally present in the clay fraction. The behaviour of clay suspensions on coagulation was found to vary in a characteristic way with the concentration of the coagulating electrolyte. When curves were obtained by plotting the height of the coagulum after 24 hours against the electrolyte concentration, the majority of the curves obtained with different clays were determined by two partially but not closely correlated variable factors, one associated with the electrolyte concentration at which the suspension gelatinised (the gelation value) and the other with the rate of settling of the gel.

Clays could be broadly classified into two main groups, one forming in a suspension of one-half per cent. stable gels and the other unstable gels which broke up into flocs after a time. Only a few of the clays from certain parent materials fall outside these two groups. Studies of the colloidal properties of a number of clays in relation to their geological origin, and the changes occurring in these properties as the parent material weathers into soil, were also carried out. The gelation value of a sedimentary clay was generally correlated with its geological origin.

The bearing of these investigations on the classification of clays and their correlation with such characters as colour has also been considered. Ultimately it is hoped that it may be possible to correlate the agricultural behaviour of a clay with its gelatinising capacity.

University College of North Wales, Bangor.

The intensive study of the soils of North Wales has been for a number of years a feature of the work of the School of Agriculture at Bangor, where Professor G. W. Robinson combines the duties of Professor of Agricultural Chemistry and specialist Advisory Officer under the Advisory Scheme of the Ministry of Agriculture and Fisheries. One result of combining soil research with the teaching of agricultural chemistry is that a number of Professor Robinson's former pupils have continued to engage in soil investigation in this country and abroad.

The field examination of Welsh soils, which is in progress by surveyors attached to the Department, is followed up by detailed laboratory investigation by Professor Robinson and his colleagues, Messrs. W. McLean and Rice Williams, who have contributed both to an understanding of the characteristics of different soil types and to methods of soil investigation. Mr. McLean, who is studying the forms in which phosphorus occurs in soils, has recently devised a quick method of estimating the total quantity of phosphorus present. After trial on 20 different soil samples collected to represent the soils of a number of countries, he finds that the method gives results corresponding very closely to those obtained by the tedious method at present followed.

Mr. Rice Williams, who is also studying the forms in which phosphorus occurs in soils, has described a method of distinguishing between phosphatic compounds existing in soils and certain minerals which depends on the use as a solvent of sodium hydroxide of appropriate strength. He points out that in ordinary soils phosphorus may be present in organic compounds, or as part of the colloidal clay complex, or in combination with iron and alumina, or in a range of calcium compounds. Using soda as a solvent, he classifies these forms as follows:—

> *Insoluble.*—Phosphorus in minerals of the apatite class (also phosphorus in such artificial manures as basic slag, bone meal and mineral phosphates).
>
> *Soluble*—Phosphorus in combination with iron and alumina, organic phosphorus, exchangeable phosphorus of the clay complex, phosphorus of such calcium compounds as occur in superphosphate.

The position of phosphorus occurring in the interior of the clay lattice is doubtful and the solubility of phosphorus in titanium compounds was not examined. It is not at present possible to distinguish between phosphorus in the organic and inorganic forms in soil, and Mr. Rice Williams is now devoting attention to this subject in the hope of effecting at least a partial separation between them.

The Welsh soils hitherto studied in the Bangor laboratory have been almost wholly those taken from agricultural land. Professor Robinson was anxious to undertake a systematic study of those horticultural soils derived from the same parent materials and exposed to the same climatic conditions which had long been subjected to different and more intensive cultural treatment. Application was made to the Council for a grant for this purpose. It was held by the Council to be desirable that the investigator proposed for this work should first study certain soils which experience elsewhere had shown to be specially adapted for the growing of bulbs, an industry for which North Wales appeared to offer favourable prospects. In 1936, therefore, the Council recommended a grant to the College of £250 from the funds at the Council's disposal on the Vote of the Ministry of Agriculture and Fisheries to initiate work on the suitability of certain soils in North Wales for bulb growing. Mr. A. J. Pugh was appointed to undertake this work under the supervision of Professor Robinson for a period of six months from the 16th July, 1936. A further grant of £350 was made for a year from the 1st April, 1937, for continuing the investigations and extending them to other horticultural soils; later in the year, however, Mr. Pugh was obliged to resign from ill health. During his relatively short period of work Mr. Pugh familiarised himself with different aspects of bulb cultivation and various types of bulb soils in Lincolnshire, Cornwall, Lancashire, Flintshire and the Netherlands. He was engaged in the laboratory study of a number of samples of the sandy soils of North Wales at the time of his resignation and this work is being continued by his successor, Mr. C. Bould. Professor G. W. Robinson has since submitted a valuable report on the work done by Mr. Pugh, compiled from his uncompleted draft and notes.

Soil work at Advisory Centres.

Though the advisory work of the specialist Advisory Officers, who are attached to the Universities, Colleges and Research Institutes serving as provincial headquarters for the Advisory Service, is not a direct concern of the Agricultural Research Council, many of these officers engage in experimental and research work of importance. This aspect of their activities includes such subjects as manurial experiments, soil deficiency problems, and the like; it is impossible to survey the work in progress under State aid in the field of soil science without some reference to it. Advisory chemists are attached to 12 of the 14 provinces into which England and Wales have been divided for the purposes of the advisory scheme; in Scotland there is an advisory soil analyst at the West of Scotland Agricultural College, a part-time adviser in agricultural chemistry with a whole time technical assistant at the Edinburgh and East of Scotland College, while the Macaulay Research Institute at Aberdeen serves also as an advisory centre for the north of Scotland in this field.

Some of the experimental work carried out by the Advisory Officers is planned on co-operative lines by committees set up for the purpose. Work planned in this manner is in progress at several centres—Bristol, Leeds, and the Harper Adams and Midland Agricultural Colleges—on the utilisation of sugar beet factory waste lime; another joint project is the study of manganese deficiencies at the Harper Adams and Midland centres; while a proposal for a survey of the lime status of soils in Great Britain, in which most of the centres would co-operate with a view to mapping the areas most in need of lime, was considered in detail at a Conference of the Advisory Chemists held at Oxford in July, 1937.

The experiments on manganese deficiency have been carried out chiefly with oats, the crop most liable to show the symptoms ("grey speck" disease) of this condition. In the West Midlands, however, similar though less marked symptoms have been observed by Mr. W. Morley Davies on wheat and sugar beet. In this area both manganese sulphate and basic slag gave a considerable degree of control, the former being the more effective when applied in quantities containing approximately equivalent amounts of manganese. Basic slag is the cheaper and it has the additional value of supplying phosphates. Farmyard manure also gave a very marked improvement. In three years' experiments the attack diminished as soil acidity increased, and it appeared that a pH value below about 6·5 was seldom associated with the disease. In 1936-7 further experiments were laid down by Mr. Morley Davies and Mr. H. T. Cranfield, the advisory officers at the Harper Adams and Midland Colleges. In these experiments the effect of manganese deficiency on other crops such as wheat and potatoes, as well as on oats, will be studied.

Injury to crops from smoke pollution is prevalent in the manufacturing districts of the north and north-central parts of the country. Cases of severe smoke damage have been recorded in Durham, Yorkshire, Cheshire and Derbyshire. Mr. H. Trefor Jones, the advisory officer at Leeds, has given considerable attention to this type of crop injury in his area, where not only winter sown arable crops but pastures may be severely affected . The most important obnoxious gases in the smoke are the oxides of sulphur; the resulting sulphurous and sulphuric acids increase both the sulphur content and the acidity of exposed soils. The fumes have been found to affect the water soluble sulphate content of the soil to a distance of six or seven miles from heavy city smoke pollution in the direction of prevailing winds. In the West Riding of Yorkshire practically the whole of the agricultural land suffers damage to a greater or less degree from this source. Liming gives to the plants a greater degree of resistance but does not completely protect them from continued pollution.

At the Midland College Mr. Cranfield has investigated the manurial value of sewage sludge. The results so far obtained indicate that under the experimental conditions the sludge can successfully replace dung, weight for weight, as the basic fertiliser for potatoes on light land. Further work to determine the losses on storage of the sludge is in progress.

Mr. A. W. Ling and Mr. W. R. Muir of the Bristol advisory centre have undertaken an examination of the so-called " teart " lands of Somerset. In these areas livestock are said to do badly and the presence of some toxic element in the soil or herbage has been suspected. Laboratory work has shown that selenium does not occur, but arsenic has been found in the herbage in amounts up to 20 parts per million and molybdenum may be present in unusual amounts in both soil and herbage. Further work is planned on this problem in collaboration with veterinary investigation and research officers.

The deterioration of strawberry plantings, which has been noticeable in many parts of the country in recent years, has had serious consequences in the important strawberry-growing area of Hampshire, where many fields show large patches in which the plants have died out. Field investigations by the staff of the Reading advisory centre indicated that the prevalence of diseases and pests may, in these cases, be correlated with soil conditions. A special research grant of £300 per annum was made for two years from the 1st September, 1936, to the University of Reading from the funds at the disposal of the Agricultural Research Council to assist Dr. F. F. Kay, the soil surveyor at Reading, in a survey of the strawberry soils concerned. Mr. H. T. Straw was appointed analytical assistant to Dr. Kay under this grant. Early in 1937 further proposals were made for extending the work on both the entomological and soil aspects of the problem, the investigations to be carried out mainly at the Botley Fruit Experimental Station of the Hampshire County Council and to receive some financial aid from the County Council. The soil work was to be supervised by Dr. Kay, with advice from Professor R. Rae, Professor of Agriculture at Reading University and Dr. T. Wallace of the Long Ashton Station, and was to include drainage and manurial experiments extending over a period of years. The Agricultural Research Council approved a further grant of £505 to cover both entomological and soil work on strawberry deterioration under the supervision of the Reading advisory officers from the 1st June, 1937, to the 31st March, 1938; the progress of the investigation is to be reviewed by the Council before further grant aid is given.

At the Seale Hayne centre Mr. A. Blenkinsop has aimed at the correlation of crop failures and of certain physiological disorders of plants of economic value in his area with soil composition. Working with a rapid method of analysis based on the composition of the water extract of the soil, he has found evidence of crop injury resulting from rapid changes in the soil balance of nutrients in winter broccoli, Brussels sprouts, lettuce, endive and violets; the "browning" disease of anemones is associated with unduly high phosphate and low nitrogen supply, while "black leg" in mangolds is prevalent where potash and lime are low. Tests are in progress of the effect of various substances on the obscure " patch " disease of strawberries. Evidence has been obtained that the disorders of cattle and sheep known as " moor sickness " on the granite soils of Devon and Cornwall are associated with magnesium deficiency, and tests of magnesian (dolomite) limestone have given promising preliminary results in improving the condition of milch cattle in these areas.

Fertiliser trials are in progress at most of the centres. From the Cambridge centre Mr. F. Hanley has conducted a number of experiments in Norfolk and Cambridgeshire on rotation manuring, with the object of determining the requisite amount of fertiliser necessary to maintain soil fertility in a rotation period covering four or five years. The work is carried out at several centres in co-operation with the County agricultural officers and the Sprowston staff. He is also carrying out laboratory and field experiments on the placement of the fertiliser and the effect of its position in the soil in relation to the seed. Mr. Hanley started in 1935, with the co-operation of the Norfolk County staff, a series of experiments on the use of boron to prevent heart rot of sugar beet and extended his observations to an examination of the residual effects, if any, on a following barley crop in the next two years. Borax and rasorite (a raw material from which borax is manufactured) were equally effective at equivalent boron contents in reducing heart rot and appeared to increase the sugar percentage in the beets slightly; no residual effect on barley was observed. Mr. Brynmor Thomas at Newcastle has found that boronated slag was approximately equal to borax at equivalent boron amounts in reducing heart rot.

Experiments on the manuring of various vegetable crops, Brussels sprouts, lettuce, cabbage, etc., are in progress in the eastern counties, on rhubarb at Leeds, on grassland at the Bristol, Leeds, Midland College, Reading, Newcastle and other centres and on flowers at Reading and Seale Hayne. At Leeds Mr. Trefor Jones has examined the value of certain gas works by-products as fertilisers; ammonium bicarbonate was found to be roughly 80 per cent. as effective as an equivalent weight of ammonium sulphate in the manuring of oats, and ammonium thiocyanate at 20 per cent. was useful as a weed killer and (when diluted) as a nitrogenous fertiliser for winter application. At the South-Eastern College, Wye, Mr. B. S. Furneaux and Mr. H. H. Glasscock found the so-called " marsh spot " of peas to be associated with a high soil water table and heavy soil texture; subsequent work elsewhere in England

and in Holland has indicated that the disease may be due to manganese deficiency. Mr. N. H. Pizer has undertaken at the same centre an investigation of the manurial requirements of cultivated mushrooms, involving a chemical study of the composts in which they are grown; the degree of dispersion of the colloids in the compost has proved to be an important factor, high dispersion preventing, and low dispersion, particularly if brought about by calcium ions, favouring mycelial growth. The addition of gypsum to the manure before composting has given results of practical value.

In Scotland much of the advisory work in this field has centred at the Macaulay Institute, the present Director of which, Dr. W. G. Ogg, was formerly Soils Advisory Officer at the Edinburgh Agricultural College. When he left, no separate appointment of an adviser in chemistry was made, but Dr. A. M. Smith, Lecturer in Chemistry, supervised the advisory work and was provided with a technical assistant paid from the advisory grant. Recently Dr. I. M. Robertson, who has had much experience of work on peat soils at the Macaulay Institute, has joined the Chemistry Department of the Edinburgh College. Apart from general studies of the fertiliser and lime requirements of the soils of the area served by this College, work is in progress there on the relation of soil and herbage deficiencies to the sheep trouble known as " border pining ". This work has shown that deficiencies in iron, copper or manganese were not involved and studies of the cobalt content are now in progress. An examination of the *Aspergillus* method of assessing fertility in routine use in the College, especially for determining potash requirements, has shown that the results compare closely with those from pot and field experiments. Other investigations include manurial rotation experiments on the College Farm and the study of the fluctuations in soil acidity due to fertiliser treatment and climatic effects. Mr. R. G. Heddle, the Edinburgh Advisory Officer in Botany, has collaborated with Dr. Ogg of the Macaulay Institute in a study of the herbage changes following different manurial treatments on poor pastures. Mr. Heddle has also done much work on the improvement of poor hill pastures by manurial and other treatments.

SOIL SURVEYS.

In the Council's First Report some account was given of the recent history of the efforts which have been made to devise a method of characterising soils as they occur in nature, so that, like rocks, they may be classified into natural groups and their boundaries delineated on maps, as geological formations are on geological maps. It was then pointed out that different methods of surveying and classifying soils had been tried out in the field and that much the most satisfactory—indeed the only method generally applicable—was that known as the profile method of surveying. This method, now generally used by soil surveyors, has resulted from pioneer work chiefly done in Russia and the United States. To the Russians, who first advanced a system of classification based on the soil's genesis in 1879, is due the study of the soil as a natural object having distinctive characteristics (mainly in the case of Russia the result of climate), which to a trained field observer reveal the soil's origin and to a large extent its properties. In 1899 the United States established a Soil Survey Department under Milton Whitney. Here the system of classification at first depended mainly on the soil's geological origin and on such physical characters as texture and colour. Experience in the field soon showed the need for a study of the soil's profile, as seen in vertical sections, and after the late C. F. Marbut succeeded Whitney as Director, in 1913, and the results of Russian studies became known to American surveyors, great improvements in field methods were effected. In the instructions to his surveyors issued by Marbut special stress was laid on the importance of closely examining and describing the soil profile, so as to gain an understanding of the soil's characteristics. He points out that " the soil is a natural body, developed by natural forces acting through natural processes on natural materials " and that it is impossible to ascertain the true characteristics of soils unless they are studied in their natural condition in the field. This view was strongly pressed by Marbut at the first meeting of the International Society of Soil Science in 1925 and largely through his influence, and that of the Russian Glinka, soil profile studies and soil classification have since received much attention in a number of countries.

Before the International Society was founded, however, the rapid progress being made by American surveyors was known in this country and the profile method of surveying was being applied to British soils, notably by Professor Robinson of Bangor, who had found earlier methods unsuitable in studying Welsh soils, and by Dr. Ogg, now of the Macaulay Institute, who has been trained in American methods in the United States.

To bring together those agriculturists who were interested in soils and members of the Geological Survey a conference was held at the offices of the Development Commission in 1923, with the result that plans for systematic collaboration between the Survey and a group of agriculturists were formulated.

The Ministry of Agriculture and Fisheries subsequently arranged for annual conferences, a small executive committee was set up and continuous field studies have since been in progress.

In the Council's Second Report a short account was given of the surveys being carried out in different parts of the country; these surveys are being continued and some reference to the results will be made in connection with the enquiry of the Sub-Committee referred to in the following paragraphs.

Sub-Committee on Soils Surveys.

In reviewing the research in progress at Research Institutes the Council ascertained that outside these institutions, and usually through the interest taken in the subject by agricultural chemists attached to Advisory Centres, a large amount of investigation on soil questions was in progress. Two agencies were active in promoting this work; one of them the Executive Committee of the Soil Conference above referred to, the other the British Section of the International Society of Soil Science. The second, which includes most of the soil workers in the Empire, is mentioned since through it British soil surveyors maintain contact with foreign workers; but it is with the work of the former that we are here concerned.

It appeared to the Council that a review of the work on surveys which had been carried on for 10 years by the Soil Conference and its Executive Committee was desirable and a Sub-Committee, with Sir Daniel Hall as Chairman, was set up in 1935 with the following terms of reference:—

> "To examine and report on the soil surveys which are at present being carried out in several parts of the country as the result of plans made by the Soil Surveyors' Conference."

If satisfied that the present rate of surveying should be accelerated and the work of the soil surveyor placed on a permanent footing, the Sub-Committee were further asked to make recommendations on the type of organisation desirable for a soil survey which might ultimately be required to extend over the whole country.

At their first meeting it was explained to the Sub-Committee that after the Conference of 1923, above referred to, much preliminary work had been undertaken before any considerable amount of field surveying began. Although it was agreed as far back as 1925 that the profile method should be followed by soil surveyors, it was found that adaptation was required to suit it to the needs of this country, where parent material was of relatively greater and climatic conditions of less importance than in the continental areas where the method originated. It was further realised that, although the principles underlying the method were easily grasped, its practice called for considerable experience. Without considerable field training in studying and describing profiles, uniformity in classifying and mapping soil could not be expected; thus, under the guidance of the Executive Committee of the Conference experimental surveys in a number of districts were undertaken and at annual field meetings those regularly engaged in surveying, with other members of Conference interested, met to survey and map test areas and to compare notes on the resulting work. By 1930 the number of surveys in progress in different areas was considerable and the Departments of Agriculture then set up a Soils Correlation Committee, which visited the localities where surveys were being made, inspected the work of surveyors, checked their descriptions of profiles, and thus assisted to secure uniformity in practice. With one exception the membership of the Correlation Committee was identical with that of the Executive Committee of the Soil Conference.

When the Council's Sub-Committee met to take evidence they began by examining the methods of surveying which had been adopted by the Soil Conference, with the object of ascertaining whether surveying by the profile system had been proved to be satisfactory as a means of identifying, classifying and mapping British soils. Evidence was invited from members of the Executive Committee of the Soil Surveyors' Conference, who in preparing their evidence agreed that different aspects of the subject should be dealt with by different members.

Professor G. W. Robinson of Bangor and Dr. Ogg of the Macaulay Institute described the methods employed by soil surveyors and the character of the work that has been undertaken in England and Wales and in Scotland respectively. Professor Hanley of Newcastle, Dr. T. Wallace of Bristol and Mr. W. Morley Davies of the Harper Adams College dealt particularly with the uses of surveys to the farmer and fruit-grower. Mr. Dines of the Geological Survey, a member of the Soils Correlation Committee, who is familiar with the methods employed by soil surveyors in the field, contrasted the work required of the geologist and agriculturist in surveying and mapping.

Summarising the evidence it may be stated that the unit of classification which has now been agreed upon for British soils is the Series; those soils whose profiles reach an agreed standard of similarity are included within the same series. The profile, or vertical section, of a soil as seen, for example, in a quarry, is usually arranged in layers, termed by surveyors " horizons ". The horizons present differences in thickness, structure, texture and colour, all of which may be noted in the field, and also in composition, which can subsequently be ascertained in the laboratory. The task of the surveyor is to record in field notes the features of the profile, to ascertain by auger borings the area over which the profile is similar and to map, usually on a scale of six inches to the mile, the boundaries where the profiles change. He must further take representative samples for analyses and make field notes on vegetation, topography and natural drainage, conditions affecting the soil's character. At the same time, or subsequently, notes on artificial drainage, management, crops, fertility and other matters of agricultural interest must be made so that full information on soil and soil quality may be recorded.

The records when complete have both an agricultural and scientific value. The pedologist, studying the origin of soils and attempting to group the soils of a country, or of a region, into classes, finds in the soil's profile the resultant of all the factors which have contributed to the soil's formation—climate, parent material, topographical position, water relationships and vegetation. In studying profiles with the object of framing a broad natural classification, attention is usually paid to virgin soils only; but in subdividing the main soil classes met with in Great Britain, the influence of man, in, e.g., forest clearings, large drainage operations and ordinary field cultivation, must be taken into account. In soil formation in this country these secondary influences have been specially important. The features of soil profiles which surveyors record in the field are not definite, but variable; although measurements may be made of the thickness of a soil horizon without any difficulty, these measurements could not be used by themselves in defining or identifying a series, since the thickness of a particular horizon may change rapidly. It might, for example, be 2—4 in. in one soil profile and 6—8 in. in another pit dug a few yards away in the same series. The effects on field work of these changes in thickness, colour, etc., which must be expected by surveyors, have been considered by the Soils Correlation Committee while inspecting many hundreds of profiles all over the country, and, as a result of the Committee's experience, it was stated that the difficulty of identifying series, because of their variation from place to place, was less of a drawback to field work than might be supposed by scientific workers handling more definite objects, such as plants or minerals. It was stated that the majority of the British soils so far met with, though not all, could be classified without difficulty into series which could be identified by competent surveyors if they were found in any part of the country. It was also claimed that as a result of their inspection of soils in many parts of the country the witnesses were satisfied that the " profile " system of classification can explain a soil's agricultural properties in a way which older methods have failed to do.

A further important point elicited in evidence was that sufficient knowledge of the methods of surveying has now been gained to justify the commencement of a systematic survey and classification of British soils, so that the pioneer work on which the Soil Surveyors' Conference has been engaged could at once be expanded if additions were made to the small staff of about half a dozen assistants at present regularly engaged in field surveys.

Although the evidence showed that sufficient experience has now been gained to enable a systematic soil survey of the whole country to be embarked upon, it also showed that much investigational work is still required. While the series which extend over large areas are not likely to be numerous (in the Midland area, where over 120,000 acres have been surveyed and some 25 series have been described, 10 series would include all the usual soils), many soils of local importance have been met with; the total number of series examined by the Soils Correlation Committee in their first three tours of inspection was over 200. Many of them, however, were tentatively admitted to the list; whether they deserve to remain will depend on further examination. Again, samples of horizons of the series already met with have been taken for laboratory examination and analytical work on them is much in arrear; it is likely that when figures are available a reduction in the number of named series will be made. Nor is it only with the object of assisting soil classification that investigation is required. It is certain that, as through field observations closer acquaintance is made with the soil, many subjects calling for research will be met with. Professor Robinson pointed out that relatively little is yet known about the constituents of the "clay fraction" of soils, and that a study of the clay fractions of the different series is much required. The need for research was also stressed by Dr. W. G. Ogg, who has been engaged in the investigation of Scottish soil problems since 1920.

The uses of Soil Surveys.

The value of soil surveys in new countries is obvious. Systematic surveys have there awaited only the discovery of suitable methods of conducting them. When, in 1899, Milton Whitney devised a plan for carrying on soil surveys in the United States and reported on extensive sample areas, the President sent the report to the Senate and House of Representatives with the message, "In the opinion of the Secretary of Agriculture this is the most important work of its kind ever undertaken," and large financial provision was made for extending operations. Canada is now following the example of the United States. In Australia soil surveys are proceeding rapidly. In African Colonies several soil surveyors trained at our agricultural institutions are being employed. In this long settled country, however, where the productive powers of every field are supposed to be known to farmers, and its rental value to local valuers, conditions may well be different, and witnesses were questioned on the agricultural value of surveys. Replies were made from different points of view. Professor Hanley of Newcastle was emphatic on the value of surveys from the point of view of agricultural planning. He has himself been engaged in mapping the broad agricultural features of the North of England, and even the few soil surveys made there showed him how greatly systematic surveys would have assisted his work. He further referred to his experience in reporting on some 800 grassland experiments in all parts of England for the Ministry of Agriculture and Fisheries. He found data accumulated by those in charge on many points, but precise data on the soil were usually absent; and thus much of the value of these experiments, in his opinion, had been lost.

Mr. W. Morley Davies, Advisory Chemist at Harper Adams College, and an experienced surveyor, described the "lost" feeling of the agricultural chemist in a new district when he was questioned about the management of soils, and contrasted this feeling with the confidence that comes to him as his soil surveys progress and the real character of the soil is understood. It is then possible for the adviser to conduct field experiments on each important soil series, to ascertain exactly how the series respond to lime and fertilisers, to form a fair estimate of the effects likely to be produced by drought or excessive rainfall, and to advise farmers on questions of soil management with some degree of confidence. An accurate knowledge of the characteristics of the soil series occurring within his area, and information about their distribution such as can be recorded on a six-inch map are, in the view of this witness, essential for agricultural chemists engaged in advisory work.

Dr. T. Wallace of Long Ashton Research Station, also a chemist, expressed similar opinions from the point of view of the research worker on fruit cultivation. Dr. Wallace has been conducting soil surveys since 1922; he began them before the " profile " system of classification had been adopted in this country, but he was quick to see its advantages to the fruit grower and he has used it extensively since it was approved for use by the Soil Surveyors' Conference. The fruit tree, with its extensive root system and perennial habit, reflects conditions in the deeper soil layers to a greater extent than annual field crops, and Dr. Wallace has been able to show a close correlation between the growth of fruit trees and different soil series. In the case of vegetable crops, where surface texture and tillage exercise so great an influence, the relation of crops to soil series is less marked than in the case of fruit trees, but even here cases were met with, as for example, among asparagus growers, where the limits of the crop are found to follow closely the boundaries of a soil series.

The experience of Dr. Wallace gained in the fruit plantations of Worcestershire and Herefordshire was confirmed by Mr. Furneaux of Wye College. Mr. Furneaux has been engaged for about 10 years in studying Kentish soils and his evidence was specially interesting as showing how much expert advice on soils has been appreciated by farmers engaged in fruit growing in the South-Eastern counties. During 1933 and 1934 alone Mr. Furneaux had advised farmers on the utilisation of some 10,000 acres for fruit growing, 2,000 acres for general farming, 1,100 acres for market gardening and 640 acres for hop-growing. As a result of this considerable experience Mr. Furneaux expressed the view that essential needs for the proper utilisation of soils are, in the first place, the systematic classification of soil series and types and the mapping of their boundaries, and in the second, the collection of all possible data about the soils from their occupiers; this information he pointed out should be followed up by experiments to settle points which the practical experience of growers could not explain.

The evidence above referred to was taken within the period covered by this Report, but the Sub-Committee's report was not ready for presentation to the Council until later. It may, however, be stated that the Sub-Committee were satisfied that a systematic soil survey of Great Britain was very desirable and also that enough experience of methods of conducting surveys had now been gained to warrant the establishment of a small corps of soil surveyors, to be employed continuously in field surveying and ancillary soil studies. As in the parallel case of the Geological Survey, work would begin in selected regions and would gradually extend to all parts of the country. During the experimental period covered by the work of the Soil Conference from six to eight surveyors have usually been engaged in field studies. The Committee's view was that a corps of about twice this number should be permanently engaged. It was estimated that with an establishment of this size the primary soil survey of Great Britain would occupy about 60 years. There are good technical reasons for spreading the work over a long period, as in the case of the Geological Survey; but there was a reason of another kind, which although it did not come up in evidence, was referred to in the Sub-Committee's discussions and influenced their recommendations.

Soil Surveys and National Defence.

The Sub-Committee agreed that from the point of view of Defence there should be maintained within the country a small corps of experts familiar with the types of soil found in Britain and with methods of soil examination, who would be able to judge rapidly of the soil's agricultural capacity, and whose services would be available for the assistance of administrators in an emergency.

The present policy is to store up fertility in grass-land with the intention that this store should be available for exploitation in any future war emergency. If an emergency were to arise the problem would be to select the most suitable, it may be five, or may be 20 per cent., of this land for tillage. The area required cannot be predicted; but with the experience of the last war available the difficulties involved in selection can be. The scheduling of land for tillage would, no doubt, as in 1917, be entrusted to local committees whose task would vary in difficulty with the area required and with the locality. In the eastern half of Britain local experience of the effects of ploughing up grass will generally be available and the task of executive committees would be relatively easy; but in the areas in which most grass land exists, that is, in those areas from which in a grave emergency most new tillage would be required, local experience would not suffice, and, as in 1917 and 1918, many questions would be referred for decision to headquarters. The decisions called for must take into account other considerations than the quality of the soil, but soil quality must always be of great importance. If, therefore, any extensive food production campaign should again be necessary there should be available (as there was not in 1917) a staff of experts familiar with the special characteristics of different soil types, who could examine and report on cases causing difficulty to local committees.

The records and maps prepared by soil surveyors would no doubt be used by future administrators, but it is the provision of a trained staff, rather than the preparation of records which the Sub-Committee held to be the immediate need, and although the Sub-Committee's report was not received until after the period now under review, the Council agree that attention should be drawn to this particular reason advanced by the Sub-Committee for establishing a Soil Survey.

IV.—PLANTS

PLANT PHYSIOLOGY.

Work on the physiology of plants is in progress at most of the research institutes dealing with crops and horticulture and is an essential part of the botanical activities of the Universities and many University Colleges. It impinges on the improvement and nutrition of crops in many directions, some of remote, some of more immediate application. The fundamental physiological processes underlying crop production require long range study which can only be carried out in fully equipped laboratories, but many physiological problems of immediate moment are encountered in the ordinary work of the research institutes.

Research Institute in Plant Physiology, Imperial College of Science and Technology, London University.

The work of this Institute was examined by a Sub-Committee of the Plants and Soils Committees of the Council in July, 1936. The Institute is housed partly at South Kensington and partly at Rothamsted, where there are better facilities for experimentation on the growing plant than in London. Additional work is carried on by members of the staff posted to the research stations at East Malling and Cheshunt. Besides the Director, Professor V. H. Blackman, and the Assistant Director, Dr. F. G. Gregory, both of whom have other duties at the College, there were at the time of the visit three graded and five non-graded members of the staff, with eight research students.

At South Kensington and Rothamsted the investigations in progress dealt with four major problems:—(1) An analysis of the physiological effects of potash deficiency; (2) the relation of respiration to protein metabolism; (3) the analysis of the process of vernalisation or hastening of maturity of cereal plants by low temperature; and (4) investigations on the stomata of leaves.

In barley, on which most of the work has been done, a medium deficiency in potassium leads to an increase in respiration and in the water content of the leaves, a reduction in carbohydrates, a normal content of protein but excess of amino acids, partial sterility of the ear and failure of stem elongation. More severe deficiency in potassium increases all these effects, except in regard to respiration, which is reduced to a normal level by carbohydrate deficiency. The influence of varying amounts of sodium, calcium and phosphorus on some of these effects of potash deficiency was under study in experiments at Rothamsted.

This work is a continuation of that commenced by Dr. Gregory a good many years ago, when he undertook an analysis of the effects of fertilisers on the occurrences in the plant prior to harvest, effects on which yield depended. The influence of nitrogen, phosphorus and potash on growth rate, tillering, extent of leaf surface and the like had been studied. The explanation of these obvious aspects was sought by studies of the metabolic changes which they induced within the plant. No one factor could be studied alone; the inter-relationship of the different factors concerned in plant growth and yield (total dry weight) was very important; and for the study of these inter-relationships large series of experiments (e.g., 25 combinations for a complete interaction experiment with nitrogen and potash) were required. These have been carried out on a pure line of Plumage Archer barley in sand cultures in the open.

The symptoms of potash deficiency in barley were found to vary according to the amounts of sodium and calcium supplied. When large amounts of sodium were supplied, the leaves were yellow, succulent and short-lived, but when calcium was supplied in large quantities, they were dark green and streaked or spotted with white or brown patches. A further symptom with high sodium and low potassium is the continued production of tillers which die off without producing ears. The water content, and hence the succulence, depends on the amounts of the three elements sodium, calcium and phosphorus which are present.

The high respiration rate of the leaves of plants deficient in potassium has been shown to be definitely related to the nitrogen metabolism. The high protein nitrogen content of such leaves indicates a very rapid protein synthesis, but the proteins formed were unstable. With extremes of potassium deficiency the reduction in carbohydrate content becomes a controlling factor in reducing respiration. Phosphorus starved leaves were shown to give high respiration rates when fed with inorganic phosphate together with sugar, but here also the main effect of phosphorus on respiration appeared to depend on its relation to nitrogen metabolism, the effect of carbohydrate metabolism being secondary.

Vernalisation due to low temperature is associated with the number of leaves produced before the ear begins to be differentiated. The process was proved to be due to a change in the embryo brought about by low temperature. Vernalisation can also be effected in plants exposed to short day conditions during their early stages, but in this case the action results from increased growth rate of the embryonic tissues. Oxygen was found to be essential for low temperature vernalisation. Exposure of the plant to high temperature, if prolonged, can eliminate the effect, but with shorter exposures varying degrees of vernalisation are effected.

Stomatal investigations at the Institute were facilitated by the use of a new type of self-recording apparatus for determining pore size. The effect of alternating light and dark periods of brief duration was to induce closure of the stomata, the maximum closure occurring with intermittent periods of 45 seconds. Intermittent lighting of one minute duration led to a great reduction in the growth of cucumbers as compared with lighting of 12 hours duration or continuous lighting; this effect was shown to be due to partial stomatal closure. The control of diffusion by the stomata was not found to be of major importance in regulating the rise or fall of assimilation that occurs with enlargement or reduction of the stomatal aperture. Transpiration was shown to be almost completely independent of stomatal aperture. When transpiration rate, stomatal aperture, water uptake and water content were simultaneously recorded, it was found that after wilting had been experimentally induced and the water supply then re-established, stomatal closure still persisted though the water content of the leaf was rapidly rising. Later, while the stomata remained at a low aperture, transpiration rapidly rose.

At the East Malling Research Station, Dr. H. L. Pearse of the Plant Physiology Institute was carrying out work to determine whether different apple stocks or stock-scion combinations varied in their capacity to take up plant nutrients. Young apple trees were grown in water culture and the culture solution analysed at intervals to determine the amount of nutrients taken up. Nitrogen, potash and phosphate were under examination. The growth rates of the trees were recorded from periodical determinations of their fresh weights and of the areas of their leaves. At an early stage of the work indications were obtained that aeration was more necessary for some stocks than for others; work on the relation of oxygen supply to nutrient uptake is being developed. The relation between the stock and scion was further under experimental study in field plots with all possible combinations of a dwarfing rootstock (East Malling No. IX) and a vigorous rootstock (No. XII) used as stock, intermediate stem piece and scion.

At East Malling also experiments were in progress to test the efficacy of the growth promoting substances, alpha naphthalene acetic acid, phenylacetic acid, beta indolyl acetic acid (hetero-auxin), and indolyl butyric acid, in stimulating the rooting of plum and pear stocks. It may be mentioned here that further experiments with these and other substances stimulating root development are in progress at the Royal Horticultural Society's Station at Wisley and at that of Imperial Chemical Industries, Ltd., at Jealott's Hill.

At the Cheshunt Experimental and Research Station Dr. B. D. Bolas and Mr. D. W. Goodall, members of the Institute's staff, were mainly concerned with the physiology of the tomato plant. In particular, the relation of the leaf system to the rest of the plant was being investigated by following the distribution to the roots and stem of the material formed by the leaves. Determinations were being made of the respiration, assimilation and translocation in each leaf of young tomato plants, and in the stem and roots. Leaves detached from the plant can be used to determine the changes in dry weight at different periods of the day. Respiration was found to be exceedingly high in the young leaves, but most of their gain in dry weight was due to a transfer of matter assimilated from the older leaves rather than to their own assimilation of fresh material. This transfer may be at a maximum in the afternoon and evening but goes on all through the 24 hours. The effect of environmental conditions, light, temperature, etc., on the growth of seedling tomatoes was under study, using the " paired plant " method of experimentation. Conclusive evidence was obtained that light intensity may rise above the optimum and cause a depression of assimilation; a balance between light and temperature is also necessary. The water content was also found to affect assimilation. Studies of the uptake of mineral nutrients were also being made.

Other work carried out by Mr. Goodall included a study of the position of the flower trusses on the tomato plant. In the summer the position of the first-formed truss was found to be related to the previous growth of the plant. At midsummer the truss was formed at a later stage in the plant's development than at other times. This is related to the length of daylight. The age of the seed also seems to affect the position of the first truss. The positions of the subsequent trusses were largely dependent on that of the first truss.

The Sub-Committee have not yet completed their consideration of the work of the Institute. Proposals for the erection of a new laboratory at Rothamsted for the use of the Imperial College workers there are also under consideration.

A special investigation of the well-known potato trouble known as "blackening" was undertaken by the Institute at the request of the Ministry of Agriculture and Fisheries in 1936. When certain potato tubers are boiled they turn black, but the cause of this is still obscure. An attempt has been made to find some empirical test other than boiling which will reveal this condition. It has been found that discs cut from the heel end of the potato will turn black on exposure to ordinary methylated spirits for 20 minutes if taken from potatoes that darken on boiling, whereas discs from potatoes that remain undarkened on boiling are not blackened by this treatment with spirit.

In this investigation, in which financial and other assistance is being provided by the Potato Marketing Board, the Rothamsted staff and Messrs. J. Lyons and Co. are co-operating.

Work on Plant Physiology at the Horticultural Stations.

Both at Long Ashton and at East Malling Research Stations work on various physiological problems concerned with fruit cultivation is in progress. This work was examined by the Sub-Committee appointed to review the work of the two Stations in 1935-6.

East Malling Research Station.—Mr. M. C. Vyvyan is the Plant Physiologist on the Station's staff, while the biochemical work under Mr. Roach has major physiological implications.

Mr. Vyvyan's work has been mainly directed to the mapping of the apple tree with a view to determining the effect of stock and manurial treatment on the distribution of stem and leaf growth in time and space. Hitherto, the influence of the stock has been the main subject of investigation; root, stem and leaf growth were separately estimated on young apple trees growing on different stocks. With the two varieties, Cox's Orange Pippin and Lane's Prince Albert, it was found that the proportion of leaf to root, when the scion was grown on a dwarfing stock (No. IX), was double that on a more vigorous one (No. XII). A very detailed census was also made of the various categories of leaves found on individual trees. These studies of the architecture of the tree were a natural development of the Station's main studies of the effect of the rooting portion of the tree on the scion. The accumulation of data involved very extensive counts and measurements, but required to be carried further if a complete picture is to be obtained. It was hoped also that these studies would throw light on the conditions leading to the development of flower buds and the increasingly important problem of biennial bearing. The formation of fruit buds is thought to be largely related to the time when vegetative growth ceases in the previous year.

The Sub-Committee thought that a good deal of this very laborious work might be carried out by a technical assistant or recorder working under Mr. Vyvyan's supervision but leaving the latter free to engage in other lines of investigation. This recommendation was endorsed by the Council.

The biochemical work carried out by Mr. Roach is, in part, also directed to throwing light on stock and scion relationships. A standard spectroscopic apparatus has been adapted to the determination of various elements taken up from the soil into the tree and their distribution within the tree. The determinations include a number of the rarer elements in the soil, such as nickel, cobalt, titanium, vanadium, silver, lead, molybdenum and boron. The possibility that the different root stocks take up these elements or some of them with greater or less facility already seems to be indicated, as there is some evidence that molybdenum may be associated with a dwarfing or precocity effect. Work on the mutual influence of stock and scion is also in progress by microchemical and polarographic methods and, in collaboration with Professor R. Robinson of Oxford, a survey of the organic constituents of fruit trees is being made as a preliminary to determining how far horticultural behaviour is reflected in organic composition.

Mr. Roach's work on the injection of plant nutrients into trees in order to make good the deficiencies in plant food ordinarily corrected by the application of fertilisers to the soil is referred to in another chapter (see p. 43). The effects of these injections on growth are also being examined. An outcome of this work of great physiological interest and of direct value is its application as a preventive of an apple disease known as Internal Cork, which is sometimes a cause of considerable loss, especially in New Zealand and Canada. Workers in the two Dominions had independently found that Internal Cork could be prevented by boron injections, and the methods worked out by Mr. Roach can be applied with considerable assurance of success to eliminate this disorder. Preliminary experiments on the cure of chlorosis of the type associated with iron shortage in fruit trees at East Malling and elsewhere have shown that the injection of iron solutions may prove a satisfactory treatment and, under certain conditions, have advantages over other methods of supplying iron.

Another aspect of the work at East Malling which the Sub-Committee found to have important physiological bearings was the study of the behaviour of apple tree roots as observed through the walls of glass-lined pits sunk in the soil down to the underlying ragstone and by means of recording instruments passing from the pits into the soil. This work, which was being carried out by Mr. W. S. Rogers of the Pomological Section and is again referred to on p. 106, was regarded as providing exceptional facilities for valuable physiological work. It has already given information on the manner and times of root formation, the reactions of the roots to rainfall and drought, and the duration of the activity of the root fibrils. Mr. Rogers' studies of available soil moisture are referred to elsewhere (see p. 44).

Long Ashton Research Station.—The chief physiological investigations in progress at the time of the Sub-Committee's visit to this Station were concerned with stock-scion relationships, the seasonal cycles of growth in the shoot and the changes in carbohydrates and nitrogen compounds in the shoots of the apple throughout the growth cycle.

The influence of scion varieties on the root growth of the stock has been under study for a number of years. These studies are to some degree the converse of those in progress at East Malling and were stated to be preliminary to chemical studies. The Long Ashton work on the influence of the stock on the scion has so far indicated that the stock effect is largely due to the stem piece and not to the roots. Dwarfing from the use of certain stocks is held to be an indication of incompatibility between stock and scion. With miscellaneous seedling stocks, the Long Ashton experience indicates that soil conditions have a greater effect on the formation of the full grown grafted tree. Differences visible when the grafts are young tend to disappear at maturity. The investigations of the seasonal cycles of growth in the shoot would, it was hoped, lead to an understanding of the factors affecting flower and fruit formation and the involved problem of biennial bearing. Dr. E. S. Smyth, the Plant Physiologist at the Station, was examining the carbohydrate-nitrogen cycle in the shoots of apple scions grown on five different stocks, with a view to relating these changes with differences in scion growth on the various stocks.

Dr. Wallace's work on the effect of mineral deficiencies and of different mineral ratios on the growth of fruit trees is referred to elsewhere in this Report (p. 40); it has close physiological and pathological implications as, for instance, in a possible relation to the development of bitter pit, one of the most serious disorders of the apple fruit.

The Sub-Committee were impressed by the number and importance of the physiological problems arising out of the pomological investigations of Mr. Hatton and his colleagues at East Malling and out of the work of Dr. Wallace and Dr. Swarbrick at Long Ashton. They thought that at each Station a first rate physiologist possessed of both experience and originality of mind was required, but recommended that if it should prove practicable to make only one such appointment in the near future, it should be at Long Ashton where, perhaps, the work was more immediately in need of physiological development.

Grass Proteins.

Knowledge of the chemical composition of the proteins of grasses and other green forage crops, of the methods for their determination and of their nutritive value has become increasingly important with more intensive grassland management and with developments such as grass drying. Professor A. C. Chibnall carried out investigations on this subject in the Biochemistry Department of the Imperial College of Science and Technology, aided by grants from Imperial Chemical Industries, Ltd., until 1936. The Agricultural Research Council decided to support this work by special research grants which amounted to £369 for the year from the 1st October, 1936, and, in addition, have made a grant of £425 to provide for the salary of an assistant (Mr. G. R. Tristram) for the work from 1st May, 1937, to 30th September, 1938.

A conference of research workers interested in the methods of protein analysis was convened by the Council in November, 1936. The inadequacy of these methods when applied to the determination of the proteins found in the leaves of grasses was stressed by Professor Chibnall, who pointed out that he could only obtain an extraction of about 30 per cent. of the total protein in the grass, that the method was very laborious, and that the proteins obtained were chemically impure. The chemical and mechanical problems involved in the preparation of a fair sample of the grass proteins were difficult. Dr. S. Morris, in describing his work on grass proteins at the Hannah Dairy Research Institute, emphasised the close correlation between the biological value of protein for maintenance and milk production in cattle and the lysine content of the protein, as well as the decrease in the latter as the grass grows older. He agreed that the methods used for the determination of the protein value were unsatisfactory. Mr. F. W. Foreman of the Institute of Animal Nutrition at Cambridge pointed out that no one had succeeded in separating the different kinds of protein in tissues in anything like their full amounts and that vegetable tissues presented special difficulties as compared with animal tissues.

In the work now in progress in Professor Chibnall's department Dr. J. W. H. Lugg, a research worker from Australia, is taking an active part, both in attempting to improve the efficiency of the methods of grass leaf protein extraction and in the determining of the amino acids present in the proteins of the individual species of grasses.

Root inhibition in poor heath soils.

Investigations carried out on behalf of the Forestry Commission by Dr. M. C. Rayner at Bedford College for Women and at Wareham indicated that in certain poor heath soils, such as occur in the latter area, root growth is inhibited, not because of a deficiency in plant nutrients, but because of some condition adverse to the biological activity of the soil. This condition causes the soil to be unfavourable to root growth and nutrition and likewise to certain microbiological activities closely bound up with these. The addition of composts to this type of soil produces a remarkable stimulation of root growth and of the formation of mycorrhiza.

Professor Neilson Jones of Bedford College suggested that substances affecting root growth might accumulate in the course of the somewhat abnormal processes of humus decomposition that probably are found in the soil at Wareham. He obtained experimental evidence that from samples of freshly collected Wareham soil a product may be obtained on warming which affects the root growth of tomatoes.

For the further study under Professor Neilson Jones of this possibility that there are formed in certain types of humus-rich soil substances deleterious to root growth, the Council made a grant to the College of a sum not exceeding £400 for a year from the 1st April, 1937. This grant has been used for the temporary appointment of a research assistant, Mr. A. G. Morton, and expenses. The subject is one that may have a considerably wider application than to the one soil type under investigation; for instance, there is practical evidence that many types of peat contain substances inhibitory to germination and plant growth. The Wareham heathland offers a favourable point of attack, as the particular type of infertility concerned seems to be very marked there.

PLANT BREEDING.

Plant Breeding Institute, Cambridge.

The staffing and work of the Plant Breeding Institute at Cambridge were reviewed by a Sub-Committee of the Plants and Soils Committees in 1936. The impending retirement of Sir Rowland Biffen from the Directorship rendered imperative the careful consideration of the staffing and future policy of the Institute. This was carried out by the Sub-Committee in consultation with the Ministry of Agriculture and Fisheries and the Central Committee for Agricultural Research Organisations of Cambridge University.

In the past, cereal breeding was the central feature of the Institute's activities, but much of this was considered to be drawing to a close. Exceptions were made in regard to spring wheats; there is need for improved varieties of these wheats in certain areas, to follow, for instance, the sugar-beet crop. Further work is also desirable on some of the hybrids between different species of *Triticum*. A continuation of the selection work in several families for desirable characters such as strength of straw, rust resistance, and the like, would naturally also be required. Active works on oats is also in progress with promise of valuable results and needs to be continued; resistance to lodging, winter-hardiness, yield, and quality are all under test in a series of selections and crosses with winter oats, while, in the spring varieties, high tillering capacity with rapid growth, large grain and low husk proportions are aimed at. One of the Institute's winter oat strains is nearly ready for handing over to the National Institute of Agricultural Botany for propagation and distribution.

In the barleys re-selections from the well-known Spratt-Archer malting barley are being continued and further qualitative testing of several selections from this and other crosses, including outstanding continental varieties crossed with the best British types of spring sown barley, is required; the effect of nitrogenous manures and of tillering on malting quality is also under investigation. Difficulties have arisen in securing the combination of stiff straw with good brewing quality, and the work is complicated by uncertainty in defining the qualities desired by the brewers. Similar work with two-rowed and six-rowed winter barleys is also being done.

In the genetical portion of the programme relating to wheat, resistance to shattering combined with a larger number of grains per spikelet proved difficult, as shattering was found to be linked with free setting; a number of strains with the desired combination appeared, however, to have been secured. Work on the genetics of early and late ripening, on disease resistance, on geographical variations in the awn and the genetical relationship between the different types, and on the inheritance of quality in wheat was also in progress. In barley the inheritance of fertility, waxiness, awning, rachilla length and date of ear emergence were all under study.

The Sub-Committee considered that the cereal work could be continued with two workers and that the study of other arable crops or pasture plants might be developed. Work was already in progress on peas, especially on field peas grown for fodder, and on a number of arable species of Brassicae (turnips, rape, cabbage, and the like).

In regard to field peas selections made at the Plant Breeding Institute from Maple, Dun and Black Eyed Susan were under trial by the National Institute of Agricultural Botany and further selections were under observation. The Marathon Maple pea bred at the Institute is already being marketed. In crosses between Dun and Maple peas it was found that there was a very strong linkage between earliness and the following characters: white flowers, unpigmented seed and leaf axils, and tallness. This linkage prevented the isolation of early, pigmented, short haulm forms. Certain crosses with forms having green peas and white flowers indicated that these carried a factor for purpling of the seed, which was normally inhibited. White hilum forms breed true for seed colour so that it was possible to establish a desirable stock for canning.

The work on the Brassicae was directed to the production of new species by hybridisation, especially in the hope of securing increased vigour as a result of polyploidy—the possession of an increased complement of chromosomes. Strains of the radish-cabbage hybrid, *Raphanobrassica,* resembling those produced in Russia but with reduced fertility, were secured and trials with them arranged. Some other crosses with radish as one of the parents were also successful, while certain foreign species such as Chinese cabbage and Abyssinian mustard were also of promise as hybrid parents. It was proposed to raise further crosses between the new forms, some of which might prove to have the increased vigour aimed at. Another method of securing the same end by the development of callus buds was employed and a considerable number raised from cabbage and *Raphanobrassica*. Toward this work the Agricultural Research Council have made research grants of £250 per annum since July, 1935, to enable the Institute to employ an assistant (Mr. H. W. Howard) additional to the regular staff. Mr. Howard has been mainly engaged in studying the causes of reduced fertility in the *Raphanobrassica* hybrids. Fertility in the progeny has already been increased. He has also been concerned in the raising of callus buds, produced both by wounding and by inoculation with the crown gall organism (*Bacterium tumefaciens*).

Dr. Hunter is carrying out work on the improvement of common sanfoin and kidney vetch. In the former, observations are being made on individual seedlings raised from seed of self-fertilised plants as well as mass observations of selections from normally pollinated plants. With kidney vetch the work is less advanced.

The Sub-Committee considered the possibilities of work at the Institute on sugar beet, in which homegrown seed of quality is required but for which a special station or sub-station might be necessary; on potatoes for which a large range of South and Central American forms are now available in various research centres; on pasture crops such as grasses and clovers, as a supplement for the eastern counties of the work of the Welsh Plant Breeding Station at Aberystwyth; on root crops such as swedes and mangolds; and on vegetable crops. As a result of their inspection, the Sub-Committee stated that they were impressed by the need for work on methods for the improvement of cross-pollinated crops. In crops such as the clovers and some pulses, in certain pasture grasses, in beets and mangolds and in the important group of the Brassicae (turnips, cabbage, rape, kale, etc.) pollination is usually effected by insects or by the wind which conveys the pollen from another plant, possibly at a considerable distance. This leads to serious difficulty in maintaining the purity of a strain. Furthermore, especially in the Brassicae, perennial pasture grasses and clovers, self pollination, by pollen from the same plant, when it does occur or is effected artificially, often results in a marked tendency to sterility, and the breeding of improved strains is thereby rendered tedious and difficult. At the present time in the production of seed of maize and sugar beet the commercial firms have found it necessary to issue hybrid seed instead of pure lines. Work on problems such as this, which are fundamental to much of the practical work on the improvement of economically important plants by breeding methods, was considered to be particularly marked out as the concern of the Cambridge Plant Breeding Institute, as it is beyond the reach of most of the other agricultural stations.

After calling attention to the trend noticeable in many parts of the country towards the growing of certain types of vegetable crops, such as beetroot and cabbage, on a farm scale, with wide spacing and light manuring in a manner quite distinct from the intensive market garden cultivation of the same crops, the Sub-Committee suggested that a close liaison between the Institute and the Horticultural Research Station might prove very profitable to both. Crops such as winter cabbages, swedes and mangolds were amongst those in which the interests of both stations might be linked.

The Central Committee for Agricultural Research Organisations at Cambridge have effected during the past year the liaison between the Plant Breeding Institute and the Horticultural Research Station suggested by the Council, and have set up a Plant Breeding and Genetics Sub-Committee for the joint consideration of the genetic and breeding work carried out at these two Stations and at the National Institute of Agricultural Botany.

At the time of the Sub-Committee's visit, the staff of the Plant Breeding Institute consisted, besides the Director, of one Grade I assistant, one in Grade II, and one part time ungraded assistant paid from the maintenance grant. The Sub-Committee considered that both the staff and the maintenance grant of the Institute were inadequate, and gave it as their opinion after a careful consideration of the whole position that the minimum staff required to carry on the work was two Grade I appointments (one new), two Grade II (one new to secure, if possible, the whole time services of the existing part time assistant), and two Grade III or ungraded with a view to Grade III appointments (both new). They considered that the Institute should have at least two junior appointments of Grade III or ungraded standing, in which training and experience in plant breeding could be obtained. They also recommended, and the Treasury subsequently sanctioned, an addition of £450 to the maintenance grant for 1936-7 to cover the deficit in the previous accounts and meet current expenditure; thereafter an addition of £250 to the existing grant might, it was thought, suffice to provide for the research facilities of the additional staff.

These recommendations were approved by the Agricultural Research Council in November, 1936. One of the new junior appointments recommended was filled in February, 1937, and proposals for filling the second have been submitted. On Sir Rowland Biffen's retirement in 1936, Dr. H. Hunter was appointed Director of the Institute.

The Horticultural Research Station, Cambridge.

The work and staffing requirements of this Station were examined by the same Sub-Committee which reported on the Plant Breeding Institute. The Station's most important work is plant breeding for the improvement of vegetable crops; it occupies a site on the University Farm adjacent to the grounds of the Institute and, as already mentioned, there are many points of contact between the two bodies.

The Horticultural Station is under the general supervision of a Committee of Management, comprising representatives of the Central Committee for Agricultural Research Organisations and the National Farmers' Union. Its main objects were defined in 1933 to be as follows:—(1) To determine the botanical and commercial characters of the more important varieties of vegetables, including those of new ones as they come on the market. (2) To produce and distribute improved varieties of vegetables; under the heading " improvement " of vegetables are included the production of stocks (*a*) uniform in type, (*b*) suitable for particular conditions of soil and climate, and (*c*) conforming to market requirements. (3) To maintain a collection of the varieties produced by the Station and from this to meet appropriate requests for pure stocks. (4) To study genetical problems as an aid to breeding and disease prevention in vegetables. (5) To study the manuring of vegetables and their diseases, pests and physiological growth defects. (6) To undertake appropriate advisory work so far as the staff resources allow, through the agency of advisory officers, county organisers and directly with growers. It will be seen that the first four of these objects are concerned with plant breeding, and the memorandum prepared in 1933 stated that the work under this head was designed to benefit vegetable growers, was not undertaken unless some definite demand for improvement existed, and had been restricted to crops considered to be of sufficient importance to justify the expenditure of time and labour on them.

The most important work in progress at the Station in 1936 was the breeding of Brussels sprouts and broccoli. There was also going on at the time of the Sub-Committee's visit a limited amount of work on cauliflowers, onions and peas, with some experiments on beans and gherkins for canning. Other aspects of the Station's activities are mentioned in the Chapters on Soils and Plant Protection of this Report (pp. 45, 146, 162).

Considerable success had been achieved by the Director, Mr. D. Boyes, in producing new and improved varieties of Brussels sprouts and broccoli. Sprouts superior in yield and quality to ordinary commercial varieties were bred at the Station and tests of these on a larger scale than can be provided at Cambridge were being carried out in several of the eastern counties. Experience had shown that it is necessary to carry out such tests in the area in which the variety will be grown; the variety which succeeds best at Cambridge will not necessarily do so in Suffolk or Bedfordshire. These trials were arranged through the County Organisers on land lent by or rented from growers. From the resulting crop, material was selected for further breeding work at the Station and also for growing seed to be distributed to growers in the county concerned. In some cases the seed was sold through the agency of " Growers' Seed Associations ". In 1935-6 about 30 acres of Brussels sprouts bred at the Station were grown under supervision from the Station in the counties of Norfolk, Suffolk, Bedfordshire, and Cambridgeshire. Testing was to be extended to Hertfordshire in the following year. Seed of four stocks was distributed to growers in Norfolk and Suffolk. In addition, arrangements were made for the growing and testing of a type of sprout which was considered to be specially suitable for canning. Nucleus stocks of all selected strains were maintained at the Station.

Work in progress on broccoli included breeding of Roscoff and of late hardy types. The former were being tested in Hampshire and the latter at Cambridge, owing to considerations of climate. About 20 acres of Roscoff broccoli are being grown at Beaulieu to supply material for further breeding work and possibly for seed distribution in 1938. The late hardy types were available for extended testing in the eastern counties in 1937. At the Station they had been exposed to very severe conditions so that only the hardiest survived. Some of those bred at the Station had proved to be markedly superior to any other late hardy broccoli varieties tested locally.

The main object of the cauliflower breeding in progress at the time of the Sub-Committee's visit was to produce early types resistant to late frosts. Two of these had reached a stage when they were ready for extended testing.

A certain number of improved onion stocks were being maintained at the Station; some of these were of commercial value, though drought and the attacks of onion fly on the bulbs had delayed the task of building them up in order to get sufficient seed for extended testing. Onion mildew had also proved troublesome. No arrangements for the distribution of these stocks had been made.

Some stocks of canning beans bred at the Station were ready for large scale trials. A small trial of gherkins bred at Cambridge against commercial pickling varieties was also being arranged. Resistance to virus diseases would be a requirement in this crop. Owing to lack of room at the Station work on these two vegetables has been postponed.

Mr. Boyes informed the Sub-Committee that it would be impossible for his staff to supervise more extended testing of the improved varieties bred at the Station beyond what had already been arranged. The area thus covered was insufficient to meet the needs of the country as a whole. There was also some difficulty in getting the growers to organise themselves into associations for the sale of the seed. There were objections to the Station entering into any form of retail trading in seed. The question of the distribution to growers of seed of improved varieties was considered by the Station Committee, the Central Committee, the Ministry and the Sub-Committee of the Council. It was held to be desirable that the plant breeders of the Station should be freed from the administrative and commercial work of producing and selling seed in bulk. After a full discussion of the problem the Sub-Committee recommended that the Management Committee of the Station should approach the Horticultural Trades Association with a view to setting up a scheme to expedite the growing on and distribution of new varieties raised at the Station. Any new variety thus sent out should bear a name which would identify it as having been raised at the Station. It was further suggested that the Management Committee should discuss with the Horticultural Trades Association the possibility of arrangements being made by the Association with its members for the growing on under inspection of the " original " seed of each new variety by one grower or a very limited number of growers such as would be within the capacity of the inspecting staff to visit and supervise, with assurance that due precautions are taken to maintain the purity of the strains.

Since these discussions the Station has abandoned the scheme of County growing of stock seed except in Norfolk, and has made arrangements for distributing the improved strains through a wholesale seed firm. The crops grown by this firm for seed production will have to be approved by the Station, who will supply at intervals fresh nucleus stocks. It is, thus, hoped to keep the stocks reasonably true to type.

The genetical work of the Station under Mr. S. O. S. Dark is closely linked with the breeding work of the Director on Brussels sprouts and onions, and at the time of the Sub-Committee's visit work was also in progress on pure line breeding in peas. With Brussels sprouts the uniformity of the families raised by self-fertilising various basic types of plants and the similarity of the plants raised from selfed seed from the main stem and from the lateral branches appeared to have been established. The very marked differences between reciprocal crosses were being investigated. An attempt was being made to break down the characteristic self-sterility of the plants and to see whether it was caused by genetic factors. Onions were being studied with a view to determining the inheritance of resistance and susceptibility to *Botrytis* disease, work which it was hoped would also give information on bulb colour inheritance. Observations were being made on the susceptibility of some of the Station's onion stocks to downy mildew, which had proved troublesome in certain varieties. In peas selection was being carried on in stocks raised at the Station, including various multi-podded types which it is intended to attempt to fix.

The Sub-Committee thought that long-range genetical investigations were outside the general scope of the Horticultural Research Station's programme, and fell more properly into that of the Plant Breeding Institute. They suggested that in planning the future development of the Station's genetical work, its bearing on Mr. Boyes's programme of breeding improved vegetables should be kept constantly in mind and that the work be so designed as to aid in the solution of his problems.

The Report on the Horticultural Research Station was adopted by the Council in November, 1936.

Broccoli Breeding at Seale Hayne Agricultural College.

At Seale Hayne College Mr. F. R. Horne is doing for the south-western counties of Devon and Cornwall similar work on the improvement of broccoli to that which Mr. Boyes is carrying out for the eastern and southern counties. It is worthy of note that the Cornish trade has expanded rapidly during recent years. Whereas in 1931 the Cornish crops were below 15,000 tons, imports from France were over 33,000 tons; in 1934 the French imports had fallen to 2,848 tons, mainly as a result of the duty on imported cauliflowers, while in 1936-7 the south-western crop despatched by rail was probably in excess of 30,000 tons. The same Sub-Committee that visited the two Cambridge Stations referred to above examined this work in the summer of 1936. It was begun in 1929 with Roscoff varieties and a few d'Angers, Italian and local Cornish stocks. These types may be distinguished into four main groups according to their date of ripening: (A) maturing from early December to early February, (B) from early January to the end of February, (C) from February to March, and (D) from mid-March to the end of April. Sufficient good (C) stocks were commercially available, so work was concentrated on the other groups. Many of the types raised at the College were obtained by selection within the Roscoff varieties, but others were got by crossing. Several of the former, including one very early type, were ready for distribution to growers for large scale testing at the time of the Sub-Committee's visit; a Roscoff-Italian cross suitable for the Scilly Isles was also ready, and some improved types from Roscoff-d'Angers crosses were coming on and would, it was hoped, be available for distribution in 1939. The County staffs were giving valuable aid in the testing of the new stocks and a committee or group, including the County Organisers, had been formed to discuss and report on the trials, which had to be carried out in different areas owing to climatic variations. It should be possible to know the real relative value of the distributed stocks for the first time in 1937 as a result of these trials. There were over 200 sub-stocks, grouped in 10 families, under observation, but many of these were being eliminated and only about half would remain in the following year. Once a strain was fully proved it should not take more than two years to multiply it to the commercial scale.

Even the inbred strains were not homozygous (genetically pure), so that selection must go on continuously. The tendency to self-sterility and loss of vigour in the plants fertilised by their own pollen could be to some extent reduced by hand cross-pollination within the family. The resistance to ring spot disease (*Mycosphaerella brassicicola*) possessed by the Roscoff types had been introduced by crossing into the normally susceptible early d'Angers types, together with an improvement in quality over the latter. One of the important aims of the work was to avoid the March glut of broccoli; varieties were also sought that could be got off the land in time for a potato crop. Genuine early Roscoffs were few and poor from the seedsman's point of view, owing to their tendency to rapid degeneration.

Here also, as at Cambridge, the question of the best organisation for securing the distribution of the seed of the improved varieties was receiving careful consideration. The prospects of forming seed growers' associations in Devon and Cornwall were good; associations were being established, but the final arrangements for the growing and sale of bulk seed of improved varieties had not been made. With a crop so extensively cross-pollinated as broccoli it would be necessary to isolate the seed crop or put a considerable area under the one variety.

The Sub-Committee, whose Report was adopted by the Council in November, 1936, recommended the provision of increased State aid for the valuable work being done at Seale Hayne College on the improvement of the broccoli crop in the south-western counties. This assistance has since been given.

In 1937 arrangements were completed between the College and the Devon Cauliflower Growers' Association for the supply of two mother seed stocks, an (A) and a (D) type, to seed growers' organisations in Devon for multiplication by one or more of the members.

The Scottish Society for Research in Plant Breeding.

This Society maintains a Plant Breeding Station at Corstorphine, outside Edinburgh. Its work was reported on by the Agricultural Research Council in 1935 and its chief results were summarised in the Council's last Report. Since then the Early Miller variety of oats bred at the Station has been introduced into cultivation and its growing has already extended outside Great Britain into Holland. About 68 acres were sown on contract for seed in the Lothians and gave excellent yields; about 52 tons of the seed were disposed of. Foundation stocks of each of the three new oats bred at Corstorphine, Elder, Bell and Early Miller, are retained at the Station for multiplication as required. In selecting further improved strains attention is directed to resistance to lodging, time of maturity, yield, quality, and germination character. The breeding of oats for the elimination of barren spikelets, the production of which in dry seasons appears to be an hereditary character, was continued. One cross has yielded strains which have remained practically free from this trouble. On the other hand a series of fourth generation hybrids between Elder and Orion, having certain desirable characters, seemed to be unusually susceptible to eelworm damage. The breeding of huskless oats for poultry feeding was continued. Extended trials of several of the Society's new oat selections were arranged with the Agricultural Colleges.

In barley, selection from Common Scotch barley was continued and the best of these strains will be further tested in the north of Scotland in co-operation with the North of Scotland College of Agriculture and the Department's Plant Registration Station at Corstorphine. New barley varieties are being produced by hybridising different types, and an attempt is also being made to develop new polyploid varieties artificially. Similar work on commercial varieties of field beans was carried on, and observations were begun on varieties of soya bean. Even when the seed was inoculated with the appropriate organism few nodules developed on the soya roots and there were none where uninoculated seed was sown; the resulting crops were light.

A number of progenies from crosses between the cultivated potato and various wild tuber-bearing Central and South American species of *Solanum* and also from interspecific crosses of the latter were raised. Back crossing of the hybrids of the first group with cultivated varieties gave several forms of some promise; this is being continued and the progenies tested under controlled conditions for resistance to blight (*Phytophthora infestans*). In March, 1936, the Society's experimental stocks of potatoes were transferred from Huntly in Aberdeenshire to the sub-station at Ainville, in Midlothian, where some additional land had been provided. Observations were continued on the effects of repeated self-fertilisation of inbred lines of cultivated potatoes, some of which have remained strong, while others show hereditary degeneration. Crosses between some of these inbred lines have been made. About 700 seedlings grown in 1937 and previous years are ready for comparative testing in field trials. Some 4,000 new seedlings will be raised from the 1937 seed. Five seedling varieties were submitted for Wart Disease immunity testing at Ormskirk, four receiving preliminary favourable reports in 1936. Three seedlings were included in the Department's Registration Trials, two for a second year and one for a final trial, in 1936; the last mentioned is a main-crop variety showing good blight resistance of the foliage in the field. Several more were submitted for the 1937 Trials. The Society's new potato, The Alness, was multiplied for sale under " Stock Seed " conditions, over eight tons being sold for seed in 1936. On the genetical side of the work with potatoes data are collected regarding the heredity of some of the more important characters of cultivated varieties.

Work on herbage plants is mainly concerned with the improvement of timothy and perennial ryegrass. Decumbent diploid timothy gives a dense low growth useful on poor dry land, while the taller forms of diploid composition are most suitable for fertile pastures. Attention is given to breeding quicker maturing and higher yielding strains in this group; some strains are being multiplied for extended distribution. Two races selected from the more commonly cultivated hexaploid forms are also being multiplied; one of them is promising as a high yielding hay strain. Experiments are also in progress on alpine timothy (*Phleum alpinum*), a tetraploid plant, which, while itself of no economic value, gives some vigorous and fertile hybrids with common timothy (*P. pratense*); triploid strains have been produced in the crosses of alpine with diploid common timothy. In perennial ryegrass a strain of late-flowering habit has been produced and seeded; further work on the breeding of productive and persistent strains is in progress. Some work on the breeding of palatable and soft-leaved pasture varieties of cocksfoot is also being carried on.

In this work various fundamental problems in the breeding and utilisation of pasture plants have been raised. These centre mainly around the behaviour of mixed populations of races of a cross-pollinated plant under different conditions of climate, soil type and competition with the natural weed and grass flora of the area. Unless an introduced strain can survive the environmental conditions that it encounters, it will fail to become established. The identification of racial differences is difficult in cultivated grasses and this has led to the use of the sea plantain, *Plantago maritima,* as a suitable plant for the statistical analysis of the influence of environment on the distribution of growth forms within a species, and their constancy over a period of years under uniform environment.

Selection for the improvement of swedes has been in progress at the Station for several years. The characters under study are appearance, including colour, size and shape, bulb weight, dry matter analysis, tendency to bolting and susceptibility to finger-and-toe disease. Some of the strains result from repeated selection and self fertilisation, some from crosses between varieties. From these, extensive records have been obtained regarding the mode of inheritance of certain characters, in order to assist in obtaining true-breeding strains. The relative cropping powers are assessed in yield trials and some strains are being multiplied for large scale testing. Some work on kale, involving the propagation of selected plants by controlled self fertilisation and the crossing of Thousand-headed and Marrow stem kales and kohl rabi, is also in progress. Various inter-specific Brassica hybrids are also being raised.

Effect has been given to several of the recommendations made by the Council in 1935 as a result of the examination of the Station by a Sub-Committee in that year. An assistant for cereal breeding and one for cytological work were appointed in 1936. The grant to the Station sanctioned by the Treasury on the recommendation of the Development Commission for work other than that on the virus diseases of plants, which is separately financed, was £1,870 in 1935-6, £2,669 in 1936-7 and £2,929 in 1937-8. This increase in the block grant reflects the favourable opinion formed by the Council of the work of the Station. It has not proved possible, however, to give effect so far to the Council's further recommendation that improved accommodation for the laboratory, administration and record keeping work of the Station should be provided.

The Welsh Plant Breeding Station, Aberystwyth.

This Station is engaged on work in the whole field of the production, maintenance and improvement of pastures; it carries out also investigations of certain arable crops, especially oats, of interest on Welsh farms. During 1937 it was the headquarters of the Fourth International Grassland Congress, of which Professor R. G. Stapledon, the Director of the Station, was President; a grant of £110 was made to the Station from the funds at the disposal of the Agricultural Research Council towards the cost of arranging, for the Congress, exhibits illustrating the scope and results of its work.

Breeding work is done mainly on pasture grasses, clovers and oats. In grasses, which are the concern of Professor Stapledon and Dr. T. J. Jenkin, it has been brought to the stage of multiplying seed supplies for marketing or for distribution for extended sward trials in respect of perennial ryegrass, timothy, cocksfoot, fescues and meadow foxtail. Work is also in progress on species of *Poa* and *Phalaris*.

Whereas most of the annual grasses (and clovers) have a high degree of self fertility, that is the power of setting seed when pollinated with their own pollen, the perennial species are mostly cross pollinated and show reduced fertility with their own pollen.

Exceptions occur in both groups and some species show variation in this character within the species; cocksfoot is normally cross fertilised, but some plants are highly self fertile. Each season from 10,000 to 20,000 grass seedlings are raised for single plant observation under spaced conditions. The material includes self pollinated, hand crossed, open (naturally) crossed and commercial or experimentally introduced seed, germinated in sterile soil in the greenhouse and planted out in May. Selected strains are carried on in clone lines, and where they show sufficient merit are passed on for the production of élite seed for multiplication. The common perennial pasture grasses have a short flowering season, and various methods of lengthening this so as to extend the period available for breeding have been tested. Bringing the plants into a cool greenhouse has had a marked effect in lengthening the breeding season by advancing the time of flowering, apparently through the action of a higher night temperature.

Strains are built up from a group of selected plants, in which the individual plants retain their identification number while the group gets a strain number. In a few cases, e.g., cocksfoot, it has proved possible to build up inbred strains, that is strains developed from a single parent and in which the subsequent pollinations are kept within the family; some lines of cocksfoot have preserved vigour when the progeny were self fertilised for five generations. But usually the strain has to be made from a group of parents, so that vigour may be maintained by cross pollination within the group; if this is not done there is inadequate cross fertility and a resulting deterioration. In perennial ryegrass loss of vigour from selfing is extreme and from inbreeding pronounced. Furthermore, since the strain is intended to produce a good sward, it is not necessarily an advantage to have such a standardised type of the grass as is given by an inbred line. A certain range of variability, if all the variants are good, may often be desirable. Thus, most of the strains of grasses such as ryegrass developed at the Station are composite, maintaining vigour by cross pollination within the group and showing a certain degree of adaptability. These multiple plant lines may be evolved either by strict genetical testing carried out by hand pollination both from different plants (cross pollination) or from the same plant (selfing); in this method the plants undergo careful testing and genetical analysis before they are selected as parents of the strain. Or they may be evolved by selecting from a mixed population desirable types and growing these on until their inherent conformity to type is established. In either case the plants are eventually tested in the greenhouse for reciprocal inter-pollination and the production of a sufficient amount of seed to test the strain under field conditions both at the Station and at selected farms in different districts. If it proves satisfactory as a sward maker and seed producer it is passed on for multiplication.

So far, the strains that have reached the stage of distribution are three of perennial ryegrass (one pasture and two hay-pasture types), three of timothy (one hexaploid pasture, one diploid pasture and one hexaploid hay), three of cocksfoot (pasture, pasture-hay and dense hay), one of meadow fescue (pasture-hay), one of red fescue and one of meadow foxtail.

When the improved strains are produced they have to be tested in seeds mixtures with other grass species and clovers. This work is under Mr. W. Davies. The mixtures of strains bred at the Station are tested against commercial seeds mixtures. The aim is to produce valuable and persistent plants for long leys and permanent pasture, and palatability, winter feed and yield for shorter leys. Besides simple trials with different mixtures of species and strains carried out in various parts of Wales (250 trials in 1937) and England (22 trials arranged with the Royal Agricultural Society) there are a great many experiments on seeds mixtures in progress at the Station. These cover different systems of management, sowing date, manuring, resistence to competition between the different species composing the mixture and with weeds and " volunteer " or naturally disseminated grasses, behaviour under grazing or cutting at different times and intensities, winter persistence and the like. As an example of one such experiment, typical of many that have been carried out, the members of the Fourth International Grassland Congress saw trials of various strains of cocksfoot bred at the Station in a mixture containing wild white clover and Station strains of meadow foxtail and red fescue grasses, in its fourth harvest year at the time of the Congress visit in July, 1937. With the same seed rate, the Station strain of pasture (" mop ") cocksfoot constituted 40 per cent. of the total herbage produced in the third harvest year, with 450 tillers per 2½ sq. ft. of area, against only 4 per cent. and 40 tillers for Danish commercial cocksfoot seed. The corresponding figures for the Station's dense hay strain, not closely inbred, were 28 per cent. and 230 tillers. The plots had been hard grazed intermittently from the outset and had formed excellent swards.

The feeding value of the Station's strains and mixtures compared with that of commercial grasses is also under study, being determined by the live weight increase of sheep grazed on the various plots. These tests have established the high nutritional value of the Station's ryegrass strains and show that no single species or strain gives as good a live weight increase as some mixtures. The final test of the merit of herbage is the reaction of the animals grazed on it, and herbage in relation to the quantity and quality of animal products formed is at the base of much of the work. Analytical work on the composition of the grasses is carried out with the co-operation of Professor T. W. Fagan of the Agricultural Chemistry Department of the University College of Wales.

An important side of the work is the study of seed production as a necessary extension of the breeding of improved strains for the seed trade. In practice, many more strains are under experiment in this section than will ever reach the market. The problems involved are almost as difficult and important as in the actual breeding. They include the avoidance of contamination by stray pollen from outside, mass flowering of the strain, the retention of the strain composition within permissible limits of variation, spacing, manuring, choice of soil, date of sowing and harvesting, management and the like. Several of the improved pasture strains are rather light seed producers but respond exceptionally well to manuring for yield of seed. Grazing may improve the seed yield of some grasses (red fescue), but generally grazing should be reduced to a minimum except immediately after the seed harvest. Most of the growing on of the stock seed of pedigree strains is done under contract on farms in several counties. The sowing and harvesting are usually supervised and the crops inspected from the Station. The seed is at present returned to the Station for conditioning, but in view of the increasing demand for the Station's stock seed the question of establishing a seed depot in closer proximity to the seed producing farms is under consideration.

The best method of introducing into farming practice the Station's improved seed, of which about 100 acres was harvested in 1937, has been under careful and prolonged consideration. In the past, growers' associations have done useful work in seed distribution, but better results were anticipated by enlisting the interest of the seed trade. Discussions with the Agricultural Seed Trade Association and the growers have recently been actively carried on with a view to the formation of a Limited Liability Company, not trading for profit, for the production and sale of certified Aberystwyth seed. This would replace existing arrangements made by the Station with some ten or twelve firms, who buy the stock seed and in some cases multiply it on a larger scale.

A series of experiments on the improvement of the pasturage in marshy or badly drained land, where rushes and sedges flourish, is also in progress. Mowing, grazing, ploughing and manuring such land have been tested over a number of years. In one field, in 1934, the ungrazed, unmown part had 50 per cent. of the herbage as rushes and 25 per cent. as weeds, while there were only 7 per cent. combined rushes and weeds with 70 per cent. pasture grasses (including 46 per cent. Yorkshire fog and bent) on the hard grazed part. The remarkable effects of mowing or grazing in improving this type of land has been confirmed on other areas.

Special grants have recently been made to the Station by the Ministry of Agriculture and Fisheries for the purchase of a grass drier and the institution of a series of experiments to test dried grass as a supplementary feed for sheep wintering in the open. In addition, arrangements have been made to examine the nutritive value of samples taken at various dates, including especially the individual species and strains available at the Station and, in conjunction with Professor Fagan, to carry out chemical examinations on the dried grass and study the effect of wilting on its composition. This work will be supplemented by a detailed examination of the botanical composition of the herbage under different systems of management.

The breeding of improved clovers and other pasture Leguminosae and their testing in seeds mixture is carried out by Captain R. D. Williams on a very extensive scale at the Aberystwyth Station. Red and white clovers are markedly self sterile, while in crimson clover hand self pollinations are fertile, but selfing naturally is almost impossible. Genetical analyses of these plants is difficult and laborious, but has been followed out on a large scale with the red and white species. In this work the loss of vegetative vigour following inbreeding has been traced. Even in the few plants of red clover that are self fertile, when productiveness from the first generation is taken at 100, it may fall to 60, 45 and 40 in the next three generations from selfed plants. The genetical causes of this self sterility have been worked out at the Station. The clovers are normally pollinated by bees and the best species to use for the purpose have been determined for red and white clovers. The plants for inter-pollination are set out in bee-proof compartments into which the appropriate bees are introduced after they are washed free from accidental contamination. Pollination of the original parents used in strain building is done by hand, as is also the pollination required for genetical analysis.

Enormous numbers of seedlings of the clovers and their allies are raised; as many as 250,000 crosses may be made in a year. There were 22,000 plants of red clover under genetical study in 1937, mostly for the investigation of linkage between various character factors—pubescence, colour, size, leaf form and the like. Strains are built up from groups of parent plants, as in the grasses. With the highly self sterile red and white clovers it is only possible to test out potential parents by a system of inter-crossing several lines in every direction (diallel crossing), but strains are also built up by selection of superior plants and combining them by controlled crossing and by brother and sister matings in a family for several generations with selection of desirable types, and ultimately crossing with other similarly brother and sister mated families. Strains of red clover are being worked up to give (1) an early flowering strain for one year leys; (2) a strain resistant to the rot disease (*Sclerotinia trifoliorum*); (3) a semi-late strain for two year leys; (4) a persistent extra-late strain for three years leys; and (5) a hardy strain for the poorer conditions. With white clover there is sought (1) an improved early strain for one to three year leys; (2) a persistent strain for long leys and permanent pasture; and (3) an improved intermediate type. In crimson clover which, unlike the others, is freely self fertile in fertilisation by hand, an attempt is being made to isolate pure line early and productive types. Work on lucerne includes the selfing of various foreign strains, so as to get pure lines from which to develop a strain suitable for the west country.

One strain each of red and white clover, the former (suitable for two and three year leys) built up from some 40 families of Welsh and Cornish origin, and the latter (a productive and persistent type) from New Zealand, Australian and indigenous forms, have reached the stage of multiplication for distribution. Preliminary trials with fourteen other strains of red and three of white clover are also in progress. Progeny testing is naturally on a much larger scale; the tests of the 1936 plantings of red clover covered the progeny of 151 crosses and 23 controls. Tests of the selected strains and their mixtures with other strains and with grasses are carried out as already described. In the marshy land reclamation experiments wild white clover is sown to test its persistence on such land under the different treatments.

Oat breeding was undertaken at the Station owing to the importance of this crop especially in the Welsh uplands. The chief aims of Mr. E. T. Jones's work are (1) to obtain varieties with improved standing qualities; (2) to breed heavy yielding winter varieties with white grain; (3) to breed good spring varieties suitable for rich, medium and poor upland soils, respectively. For the latter conditions selections of *Avena strigosa* and crosses between this species and *A. brevis* have been made; a selection from one of these crosses is very promising as a new variety having a high straw yield, good quality grain, a small awn and low husk pecentage, smut resistance and lateness in maturing. A number of selections from the common *A. sativa* are also under test and there are experiments in seed production. Genetical work on oats includes the study of inheritance of certain characters in diploid, tetraploid and hexaploid crosses, with studies of the influence of black and grey grain colour.

Amongst the miscellaneous researches carried out by the Station Staff mention should be made of Mr. W. E. J. Milton's studies of the buried viable seed population of hill pastures and fields, published in 1936. These showed the presence of very large quantities of seed of *Agrostis* and *Holcus* and indicated why these grasses might replace sown species in the older swards. Samples taken to a depth of five to seven inches showed that there might be as many as 73 million viable seeds to the acre under a young ley but only 7·7 million under a natural pasture. The quantities of each species found were determined and the results were grouped into frequency tables.

The Station has carried out extensive work on the improvement of hill pastures at various out-centres. These include many manurial trials with and without grazing, tests of cultivation methods, seeds mixtures, persistence and the like. A full account of the results was published as a Bulletin of the Station in 1936. In 1933 the large scale Cahn Hill Improvement Scheme was started by private benefaction. Its object was to test out on a very large scale (the Scheme covers some 3,000 acres) the various treatments suggested by the earlier experiments, taking full account of the economics of the undertaking. The Scheme, though outside the work of the Station, is under the direction of Professor Stapledon and there is a close linkage in its working with the extension activities of the Station.

The work of the Welsh Plant Breeding Station under Professor Stapledon's direction has obtained world-wide recognition. It goes far beyond the limits of that of a plant breeding station as generally understood. Professor Stapledon is the protagonist of pasture improvement in Great Britain; no aspect of this matter of outstanding importance has been overlooked and the energy, enthusiasm and ability with which the many and difficult problems have been attacked are now achieving results of great promise.

The National Institute of Agricultural Botany, Cambridge.

At the suggestion of the Ministry of Agriculture and Fisheries a Joint Committee of the Council and the Ministry conducted in 1937 an enquiry into the work and finances of the National Institute of Agricultural Botany at Cambridge. The Committee visited the Institute in April, 1937, and held a further meeting at Dean's Yard on the following day, after which certain members visited the Institute's crop testing station at the Harper Adams Agricultural College and their potato testing station at Ormskirk in Lancashire.

As this Committee has not yet reported, a consideration of the current work and position of the Institute may be deferred until the Council's next Report. A summary account of its activities, as seen by the Plants and Soils Committees in July, 1932, was published in the first Report of the Council in 1934.

The John Innes Horticultural Institution, Merton.

Most of the current work of the John Innes Institution is concerned with plant genetics and breeding. The plants under study are in large part selected because of their genetical interest rather than of their economic value, but some of the work has a more direct practical bearing on the improvement of fruit, flowers and vegetables.

The fruit breeding work is aided by a grant from the Ministry of Agriculture and Fisheries and is particularly concerned with the cytological study of the apple, pear, plum, cherry and various species of Rubi (raspberries, blackberries, loganberries, etc.). The work was commenced as purely genetical research, but promising new varieties of fruit appeared during its progress and it was considered desirable to grow on and test the more likely of the seedlings for their probable commercial value. Several of the fruit varieties bred at the Institution are under test in the National Fruit Trials at the Royal Horticultural Society's Garden at Wisley and elsewhere. Three apple seedlings have been handed over for commercial distribution.

The study of cross- and self-fertilisation in apples, pears, plums and cherries was begun by Mr. M. B. Crane a good many years ago. The work showed that all the sweet cherries (*Prunus avium*) are diploids and self sterile. Out of 66 varieties examined, 47 fall into eleven groups, the members of which are also incompatible when fertilised within the group. The incompatibility is due to failure of the pollen tube to grow down the full length of the style into the ovary. The sour cherries (*P. cerasus*) are tetraploids and there are various degrees of self- and cross-incompatibility and partial self-compatibility among the varieties. The domestic plums are hexaploids and contain groups of self- and cross-incompatible varieties. In some cases pollination is effective in one direction between a pair of varieties but not in the other. Particular attention is being paid to the Gage group, most of which are self-incompatible.

The apples contain diploid and triploid varieties of rather complex chromosome constitution and show various degrees of self-sterility and self-fertility; none is completely self sterile. The triploids are productive but have a low fertility when crossed with pollen of other diploids and triploids. Studies of the inheritance of characters in the apple have shown that such characters as colour of skin, shape and size of the fruit are usually inherited in a graded fashion. Extended studies of some of the cross-bred families have been carried out. Thus, a study of the inheritance of the dwarfing character of two of the East Malling stocks, carried out in collaboration with the staff of that Station, has yielded results of value in relation to precocity of bearing, disease resistance, productivity and other characters. The inheritance of resistance to the woolly aphis shown by Northern Spy stocks is heritable and can be introduced into crosses between Northern Spy and the more valuable Paradise stocks, which can be readily propagated in a vegetative manner. Several immune seedlings of this type are undergoing tests as stocks at East Malling and elsewhere, and much of the work in raising and testing the stocks has been done in conjunction with the East Malling staff and is again referred to in a subsequent section (p. 107). An interesting point which has emerged in this work is that some of the susceptible varieties of apple carry genetic factors which are concerned with immunity. The results in general indicate that the hereditary behaviour of apples immune from woolly aphis is determined by and dependent on a certain balance of genetic factors; it is governed by a number of genes, some complementary and some cumulative. Work on the inheritance of resistance to red spider in apples has been begun.

Pears resemble apples in including diploid and triploid varieties whose behaviour in breeding is in general similar to that of the apple. Work on sterility and incompatibility in pears is actively in progress; four out of the 16 varieties tested have proved to be self sterile.

Extensive investigations on indigenous and cultivated varieties of Rubi are being carried on. In these plants polyploidy is common, and the wild forms have diploid, tetraploid, pentaploid, hexaploid and octoploid forms. The cultivated raspberries are sometimes diploid, sometimes tetraploid; the loganberry is a hexaploid. A tetraploid thornless variety of blackberry has emerged at the Institution and has been introduced into commerce together with two other blackberry varieties. Crosses of the loganberry and of raspberries with *Rubus ursinus* give a series of familes with from three- to five-lobed leaves which are under analysis.

In support of the work of the fruit department of the Institute a grant of £885 was sanctioned from the Development Fund on the advice of the Agricultural Research Council on the application of the Ministry of Agriculture and Fisheries for the year from 1st October, 1935, to provide for a cytologist, an assistant pomologist, and the part time services of a biochemist. This grant was renewed in the following year.

In 1936 a special research grant of £200 for a year from the 1st October was made from the Council's funds for the continuance of work on the breeding of early varieties of " Sweet Corn " types of maize, which had been commenced at the Institution by a displaced German geneticist supported by private benefaction until he obtained an appointment in Brazil. Hitherto the relatively small quantities of this cereal used as a vegetable in Great Britain have been grown from imported seed, but it is thought that it may be possible to breed varieties more suitable in regard to productiveness and early maturity for the climatic conditions of this country. An early variety grown in the Tyrol at high altitudes has been used for crossing with American sweet corn varieties.

Mr. C. D. R. Dawson was appointed to carry on this work. The production of pure lines of maize by self fertilisation presents difficulties, as the selfed progeny loses vigour. The practice in America is to establish several pure lines which are crossed in pairs to secure an F_1 hybrid possessing hybrid vigour. Crosses between these hybrids give the seed of commerce. So far, a number of excellent plants have been selected and it is hoped that in two or three years a sufficient number of pure lines will have been tested to enable the basic material to be handed over to seed growers.

Fundamental cytological work at the Institution consists of studies of chromosome behaviour in a variety of plants and animals, including the above-mentioned fruits which are being bred experimentally in order to elucidate their breeding behaviour. One of the objects in view is to obtain new races of productive fruits with new chromosome complements as, for instance, tetraploid varieties of plums, apples and pears. The biochemical work on fruits supported by the grant from the Development Fund is directed mainly to the investigation of the pigments of the apple, cherry, plum, raspberry, and blackberry. Similar studies in flowers in order to elucidate the nature of the genes responsible for different types of colour have shown a striking uniformity of their behaviour for each particular type and the additive effect, in some cases at least, when there are more than one gene involved in a shift towards a certain colour.

Fruit breeding at the Long Ashton and East Malling Research Stations.

The fruit breeding work at Long Ashton and East Malling is referred to in the account of the work of these stations on pp. 98, 108).

Hop breeding at the South Eastern Agricultural College, Wye.

The main breeding work for the improvement of the small but valuable hop crop is centred at the South-Eastern Agricultural College at Wye in Kent, the testing of the seedlings being done in collaboration with East Malling. It has been directed to meet the needs of the brewing trade and to reduce loss from disease. Several new varieties with improved qualities in these respects have found favour and are extending into cultivation. Some of these come from interspecific crosses between *Humulus lupulus* and *H. americanus,* one of which, known as Brewer's Favourite, appears to be highly resistant to the nettle-head disease, which sometimes renders gardens of the commonly grown Fuggle variety unproductive.

The improvement of University facilities for genetical teaching and research.

In 1932 the Council discussed with representatives of the University of London the provision of improved facilities for genetical teaching and research in its bearing on agriculture. In a further review of the position in 1936, the Council were perturbed to find that, while there had been some improvement as a result of the earlier discussions, these were in no measure equal to present day needs. Informal discussions, in which members of the Universities of London and Cambridge took part, showed that in both these Universities the nucleus for a properly equipped school of genetics exists, but that to establish such a school on an adequate scale in either or both of these centres a considerable effort would be required. The Council are fully convinced of the need for such a development and desirous of doing what they can to stimulate it. The recent creation of a Chair of Biometry at University College, London, marks an important step towards satisfying this need. Professor J. B. S. Haldane has resigned from his part time work at the John Innes Horticultural Institution on appointment to this Chair.

HORTICULTURE AND FRUIT RESEARCH.

Since 1911 when, through funds provided for research by the Development and Road Improvement Funds Act, 1909, it first became possible to make substantial provision for research on fruit crops, the importance of the fruit-growing industry has greatly increased. The Censuses of Production made in the years 1908, 1925 and 1931 show a rise in the estimated value of the fruit crops of Great Britain from £4,495,000 in 1908 to £7,800,000 in 1931; but since quantities and values are both subject to wide variations in different seasons these figures give no more than a rough indication of the position of an industry which now covers well over 300,000 acres (317,000 in 1936). No section of the agricultural community has shown more enterprise, or greater readiness to adopt improved methods during the post-war period than those engaged in fruit growing. In their efforts to improve upon former practices great assistance has been given to growers by the research workers, especially of the two chief horticultural research stations at Long Ashton and East Malling and by that for glasshouse fruit and vegetables at Cheshunt. Having won the grower's confidence and having in many ways given a new orientation to the grower's efforts, it is believed by the Agricultural Research Council to be of great importance that the efficiency of these stations should not only be maintained but increased. A Sub-Committee was appointed by the Plants and Soils Committees of the Council to visit the stations at Long Ashton and East Malling and their report, adopted by the Council in November, 1936, recommended some increase in the resources of both stations in order to meet the increasing and insistent demands of the industry for information;

to provide fundamental knowledge, the absence of which was holding up research; and to develop the study of new problems, such as that of the utilisation of low grades of fruit.

The visiting Sub-Committee pointed out that the East Malling and Long Ashton Research Stations, though dealing with similar subjects, are in no sense duplicates. The industry is developing under different natural conditions in different parts of the country. A result is that the researches at both centres bear very directly on the practical problems of the grower. The pressure for information, in itself a most encouraging feature of the post-war fruit-growing industry, has, however, had certain disadvantages from the point of view of the stations' own development. To these defects the Sub-Committee drew attention, and they suggested certain new appointments to the staffs which would, they believed, constitute both direct additions to the man-power of the Institutes and would have the effect of bringing up research in certain of the subjects to the high level to which the work at East Malling and Long Ashton is expected to attain, and which they considered in general, it had attained. They found clear evidence that the pomological work, for instance, was being held up in both stations in certain directions for the want of more knowledge of fundamental matters.

Long Ashton Research Station.

The Agricultural and Horticultural Research Station of the University of Bristol at Long Ashton has a Governing Body constituted by the University and including representatives of the University, the National Fruit and Cider Institute, the Ministry of Agriculture and Fisheries, the County Councils of the neighbouring counties and the National Canners' Association. Its income from all sources was £19,322 in 1934-5 and of this the grant from the Development Fund accounted for £14,175.

Pomology forms the largest part of the work in progress in the plantations. The physiological aspects of the pomological work have been referred to in the section on Plant Physiology (p. 71). Mr. Spinks, Dr. Swarbrick and their colleagues are engaged in studies of the effect of the rootstock on the scion and the scion on the rootstock in apples, on double working with apples, on pruning and tree building in apples and plums, on pruning in gooseberries and black currants, on thinning in apples, on compatible and incompatible stocks for plums and apples, on pear stocks, and on the cause and prevention of biennial bearing in apples. Dr. Swarbrick and Dr. W. E. Berry have had in progress for a number of years a series of statistically controlled comparative yield trials with several well known and other varieties of black currants. In these trials the effects of hard as against light pruning were tested, with results definitely in favour of the latter method. Mr. Spinks is engaged in an intensive study of the variability of apple trees on seedling and on clone rootstocks. Up to five years old the variability does not seem to be significantly greater in the former than in the latter as regards size and weight. In older trees variability in height and stem girth was greater in the mixed seedlings than in the clones. Studies are also in progress on periodicity of growth in different types of stock and in different scions worked on the same type of stock. A large experiment with four cider varieties of apples to study rootstock effects, the effect of the length of stem of the stock, early bearing, and the like, has also been undertaken. The effect of pruning and bark ringing on juice quality will be tested on these cider plots.

Mr. Spinks has been responsible for a very extensive programme of breeding new varieties of pome, stone and small fruits. The tests of these occupy a considerable area in the plantations and the most promising are also tested by selected fruit growers in various parts of the Bristol Province. Several named new varieties of apples, pears and plums have already been distributed and two of raspberries that have given heavy yields at the Station are under extended testing. The inheritance of various characters in the apple has been studied in 1,300 apple seedlings, included in 69 families, raised from the seed of dessert, culinary and cider varieties. No sharp segregation of characters has been found and this is in agreement with the work at the John Innes Institution showing that the apples have the genetical constitution of polyploids in which several chromosomes are concerned with the transmission of any one character. A valuable series of crosses has been secured between the hardy and vigorous Preussen raspberry and the mosaic resistant Viking variety. Strawberry breeding has presented special difficulties, owing to the tendency of so many of the seedlings to become unhealthy and weak; one seedling variety from a cross between Tardive de Leopold and Royal Sovereign is being multiplied as an early, vigorous type almost equal to Royal Sovereign in flavour.

The Sub-Committee agreed with the Station authorities that it would be advisable to curtail considerably the breeding programme, concentrating mainly on the production of varieties with specific properties, such as vigour and disease-resistance.

The breeding of cider apple varieties will also be continued, as there is much scope for improvement in this class. This decision to reduce very considerably the number of fruit varieties offered for commercial distribution is in harmony with a similar movement in regard to many other crops in other European countries, such as Holland and Germany. It will reduce the pressure on the plantation area of the Station and set free plots for other important experiments.

The important work of Dr. Wallace on plant nutrition has been referred to in Chapter III of this Report. Much of it is linked with the pomological work, especially in its bearing on the major problems of the influence of the stock and scion on one another, and of the carbon-nitrogen cycle in relation to periodicity in growth and development. Much work is in progress also under Dr. Wallace's supervision on the effect of various types of soil management on the growth of the tree, and an exact experiment on the effect on the metabolism of the tree of such soil treatments as clean cultivation, grass, grass cut and removed as hay, and the like is being arranged. A further series of experiments deals with the influence of cultural conditions on the keeping quality of the fruit. For this purpose a cold store, originally provided by the Empire Marketing Board, is used. This work was regarded by the Sub-Committee as being closely connected with the Station's general work, and their recommendation that the grant for it should be merged with the block grant to the Station, instead of being separately provided as hitherto, has been since adopted.

The Sub-Committee drew attention to the relatively slender knowledge available of the finer details of the graft union in the apple. They considered that exact anatomical-physiological studies on this point would be likely to be helpful to certain aspects of the field work in pomology and also be complementary to Dr. Wallace's interesting and important work on periodicity in the different stock-scion combinations, as linked with such matters as the renewal of cambial activity in the spring.

Situated in the main cider making part of the country and the original site of the National Cider Institute, the work on fruit products at Long Ashton probably equals in importance that on the fruit itself. It has grown recently, as a result of the increasing public demand for higher grade fruit and the need of finding an outlet for cull apples and other fruit of low grade. The use of culinary apple juices is increasing yearly and this has increased the necessity for further studies on the chemistry of the apple and on the reactions that occur during pressing and storing the juice. Culinary apples are relatively high in nitrogen and tend to give a quicker fermentation than cider varieties; experiments in slowing this down by centrifuging are in progress at Long Ashton. The keeping life of the cider can also be lengthened by centrifuging. Refrigeration experiments are being carried out in order to obtain more concentrated apple and other juices and also to test the French method of chilling the juice for cider making to precipitate heavy substances.

On the chemical side Mr. Charley is giving attention mainly to the sugars and pectin. He is following the alterations in the former during the course of fermentation. In regard to pectin he has found that all the soluble pectin originally present (less than 0·3 per cent. in the juices he has examined) disappears after fermention; this also occurred even when by extracting the pomace with water he had added 0·3 or 0·4 per cent. of soluble pectin to the juice. When the juice is pasteurised before fermentation the pectin is not subsequently lost on adding yeasts; apparently there is something in apple juice which, with yeasts, can decompose pectin but which is destroyed by heating.

Professor Barker and Mr. Charley acquainted the Sub-Committee with the great interest which is being taken by growers and the cider industry in their new work on fruit juices other than cider. These include new fruit juices, fruit syrups, alcoholic drinks, and squashes. The milk bars that are springing up in various parts of the country would, they thought, utilise a proportion of these drinks in preference to the synthetic materials now mainly used. Problems under study include methods of clarifying the juices, the determination of the optimum sugar:acid ratio, and the problem of keeping the juices sweet for, say, a year in store. Tests are being made of various substances with a view to removing the " harsh " flavour of culinary apple juices. A new apple juice with a low alcohol content is being made. Cider vinegar and cider brandy (the French " Calvados ") are also under investigation, and an attempt is being made to use culinary apples for the latter.

In 1936 several firms began production of fruit juices according to the methods recommended by the Station as a result of Mr. Charley's work. Arrangements were made for him to exercise technical control for a limited period of the manufacturing processes of a Bristol firm, with mutual advantage. His advisory work showed a marked increase and his services were in much demand for visits to factories that were commencing to make syrups and other products, more especially those for use with milk.

On the microbiological side work is in progress on "cider sickness", on the bacteriology of ciders, and on the use of pure yeasts which give the juice special characters. Since Mr. Charley succeeded Mr. Grove in this section, microbiological work has not been extensively carried on.

Among the miscellaneous activities of the section, mention may be made of the tests of pomace as a cattle feed and the effort to gain information on the correlation between orchard factors and vintage performance in ciders. Experiments are also in progress on the best type of container for cider and other fruit juices.

Work on the preservation of fruit pulps and jams by the use of sulphur dioxide, initiated many years ago by Professor Barker and Mr. Grove, has been continued by Mr. Charley. Methods of keeping the SO_2 content of the finished jam down to the Ministry of Health's limit of 40 parts per million have been evolved in a cold process, but when heat is used it is more difficult to avoid an excess. The determination of the proportion of free SO_2 and of that fixed in the pulp, stones or skin of the fruit has been carried out in plums and was under study in black currants at the time of the Sub-Committee's visit.

Long Ashton is also responsible for some of the examinations carried out under the National Mark Jam Scheme.

The Sub-Committee recognised the increased importance of the work of this section of the Long Ashton Station. They recommended the immediate appointment of an assistant to aid Mr. Charley in the work at present in progress. They also considered that there was need for a microbiologist to control the fermention processes involved in the manufacture of some of the new products and to conduct further investigations into the microbiology of cider making. Work on fruit products will become at a certain point the concern of the Department of Scientific and Industrial Research rather than of the Agricultural Research Council and the Departments of Agriculture. This has been accepted by the transfer mentioned in the Council's last Report of responsibility for the Fruit and Vegetable Preservation Research Station, Chipping Campden, to the Department of Scientific and Industrial Research. But that Station deals with the fruit and vegetable canning industry, and its problems are in the main factory problems. Work on fruit juices at Long Ashton, on the other hand, is primarily concerned with the qualities of the raw material and the changes it undergoes during its transformation into beverage; the immediate problems are not factory problems but biological and chemical ones deriving largely from the fruit itself. It bears the same relation to the fruit growing industry that dairying does to the cattle industry. The increasing importance of the work on fruit juices is a reflection of the requirement of the grower to find a use for the lower grades of his fruit and the work itself can be regarded as an extension of the investigations on cider in order to meet a new need.

The Sub-Committee considered this work as belonging properly to the sphere of the National Fruit and Cider Institute's functions. They were less convinced that the same could be said for the laboratory work on fruit pulps and jams in progress at the time of their visit. They understood that Professor Barker proposed to take up a study of the suitability of existing fruit varieties for jam making, work on which comparatively little had been done hitherto in this country. This would seem to be a direction in which the facilities available at the Station could be more usefully employed than in the study of jam and pulp preservation and to be more closely related than the latter to the general programme of the Station.

The expansion of the work of the Fruit Products section will necessitate some expansion of accommodation. The Sub-Committee did not feel in a position to make any specific recommendations on this matter until more was known regarding the eventual staffing and future activities of the section.

East Malling Research Station.

The East Malling Research Station was established on a modest scale in 1913. Its early work on the influence of the stocks used for apple trees was fortunate in arousing the interest of Kentish fruit growers to a marked degree. This led to the formation in 1921 of the Kent Incorporated Society for promoting experiments in Horticulture, and a rapid development of the Station with the strong support of the local growers. During the next ten years most of the existing laboratories were erected by grants from the Development Fund, the Empire Marketing Board and private subscribers. In the year ending the 31st July, 1935, the last completed year before the visit of the Sub-Committee mentioned in previous pages, the income of the Station was £17,915, of which £15,636 was a contribution from the Development Fund for the academic year 1934-5. This did not include membership fees, income from a Trustees' holding of 30 acres purchased from a special endowment fund raised from subscribers some eight years ago and worked on commercial lines, nor receipts from the sale of the produce of the experimental plantations.

The management of the Station is in the hands of an Executive Committee formed from the Governing Members of the Kent Incorporated Society for promoting experiments in Horticulture and containing representatives of the Ministry of Agriculture and Fisheries, the Universities, the Royal Society, the Wye Agricultural College, the John Innes Institution, the National Farmers' Union, the County Councils of neighbouring counties and the Institute of Brewing.

The detailed programme of the work of the Station given to the Sub-Committee at the time of their visit showed that over 100 projects were engaging the attention of a staff of 33 workers. The Station has been promoted largely by fruit growers who have learned to bring, and have been encouraged to bring, the many unsolved problems that they meet in daily practice to East Malling. There is thus great pressure on the Director and his staff and this is bound to continue. Nor is there any disposition at the Station to escape the demands made on it, for the questions raised are of both scientific and practical importance. Perhaps the most notable feature of the programme is its concentration on problems which arise in the field and are taken to the laboratory. East Malling is fortunate in possessing in its statistical section under Mr. T. Hoblyn an important safeguard in the handling of the mass of experiments and material provided by its plots. This ensures the planning of the experiments in a manner that will enable significant conclusions to be drawn by the statistical analysis of the data. Mr. Hoblyn has evolved methods of tree recording and obtaining other data required in dealing with horticultural crops.

In other branches of the work, especially in physiology, the Sub-Committee advised that a closer linking with institutions where experience is available should be aimed at. The untimely death of Dr. R. C. Knight deprived the Station of a valued and long-established link with the Physiological Institute of the Imperial College of Science and Technology; but liaison has been restored by the appointment of Dr. H. L. Pearse from the staff of the Institute to work at East Malling. In other directions the Agricultural Research Council hope to be of some assistance in arranging for the pooling of experience, as has already been effected in great measure in the field of insecticide and fungicide research by the meetings of the workers in this field arranged periodically by the Council's Insecticide and Fungicide Committee.

The largest of the sections at the Station is pomology, in which the Director had nine assistants in 1936. The study of the influence of the stock on the habit and quality of fruit trees has remained a central feature of the work of the Station since its early days. It commenced with an investigation of vegetatively raised so-called " Paradise " apple rootstocks and the contrasting " free " or " Crab " seedling stocks. There were found to be many varieties represented in these classes, some named, some unnamed, but none really pure; sixteen types having distinctive characters were separated out and standardized as the well-known Malling series of stock types. Six of these are now established in more or less common commercial use; they vary not only in suitability to different conditions, habit, and management requirements, but also in response to manuring, age and vigour of cropping, and reaction to disease.

Very full records of a number of apple varieties grown on these stocks, including measurements of vigour (total length of new wood, spread of the top, girth of trunk, etc.) and of productivity (number of blossom trusses, proportion of blossoms fertilised, proportion of formed fruit remaining to cropping, etc.) have been made; many records of single trees since 1919 are now available. In some cases, the total weight of the tree at a certain age, the proportionate weight of crop to weight of the tree, and the size and distribution of the root system, were also determined. In some of the varieties grafted on Malling No. XII stock the full effects cannot yet be seen, as they have not yielded a full crop though 18 years old.

The experiments carried out have convinced Dr. Hatton and his co-workers that the influence of the apple rootstock on the scion depends on the root. In their experience, which in this respect does not agree with the conclusions of the Long Ashton workers, the stem piece of the stock that remains below the graft has not been found to produce any significant effect. Anatomical studies of the root collar and stem are being carried out by Miss Beakbane, but the need for more exact knowledge of the finer details of the actual graft union in the apple was stressed by the Sub-Committee.

Top working apples by stub grafting has been successfully applied to large trees so as to effect a change in the bearing variety. A large number of wedge grafts are inserted in slits in the upper surface of the lateral branches, reaching nearly to the centre of the branch, which is then cut off above the graft. By this means the variety can be entirely changed and a crop of the new variety obtained in two or three years.

Work is also in progress on pear and quince rootstocks for pears, among which incompatibility is a marked feature; on plum stocks, where resistance to disease and to certain weather conditions is of importance; on pruning in all the tree fruits; on inarching for the improvement of apples on poor stocks; on the cause of non-setting of pear fruits; on thinning, especially in apples and plums; on nursery technique and tree building. In cherries varietal studies on a large collection of the sweet and acid species have been carried out. Wide variations in resistance to the bacterial canker or die back (*Pseudomonas mors-prunorum* and *Ps. prunicola*) of sweet cherries have been found to occur from one variety to another. Some are so susceptible that it has not proved possible at East Malling to grow them to fruiting age. Others have usually been free from serious injury. Studies of reliability in cropping and market quality have also been made.

Realisation of the importance of the root system in the different stocks has led to detailed studies of apple roots while still in the soil. Some of these are carried out in the partially glass-lined pits referred to on p. 71. The roots visible through the glass are measured periodically and some can be removed for more detailed examination by means of detachable panes. Soil temperature and moisture determinations are made by instruments inserted in the side of the pit at different depths. The influence on the growth of the roots of soil moisture, temperature, time of year and the like are thus measured, and the behaviour of the roots in colonising areas of the soil followed. Besides these methods made use of by Mr. W. S. Rogers for the study *in situ* of root development and function, Mr. Rogers, Mr. Vyvyan and Mr. Tydeman have carried out a number of analyses of root systems based on the excavation of the whole of the roots. Two methods of excavation, the "Skeleton" and the "Block", are used according as to whether it is desired to map on a plan the distribution of the roots, or to determine the proportion of roots of various sizes.

The pomological work on small fruits—currants, raspberries and other Rubi, strawberries—is largely influenced by the requirements of other sections of the work at East Malling. Collections of named and classified varieties have been established and clonal lines maintained for use in the pathological and entomological work on raspberries and strawberries. Long period cropping trials are in progress with currants. Miss Beakbane is engaged on detailed systematic and varietal work on various Rubi, and the effect of different methods of training on the control of loganberry cane spot (*Elsinoe veneta*) is also under study.

Work on walnuts, aided by grants from the Royal Horticultural and Agricultural Societies, is directed mainly to finding a method for the production of vegetatively propagated trees and to field trials of selected varieties thus propagated. Mr. F. H. Beard is in charge of the hop work which the Station carries on, in part in collaboration with the South Eastern Agricultural College, Wye, on some nine acres of plantations. The work includes cropping trials with commercial varieties raised in clonal races, manurial and cultural investigations. The new seedlings obtained from the Wye College are studied under field conditions for their horticultural characters and behaviour in regard to downy mildew (*Pseudoperonospora humuli*). Marked variations in the latter respect have been found amongst the varieties grown, especially in the degree to which the "cones" of the hop are attacked.

Mr. H. M. Tydeman is responsible for much of the fruit-breeding work at East Malling. An interesting aspect of it is the breeding of apple rootstocks immune from woolly aphis but of superior quality to the more generally known immune stocks now available (Northern Spy and related types). This work has been in progress for several years in collaboration with Mr. M. B. Crane of the John Innes Horticultural Institution (see p. 94) and the entomologists at East Malling. Mr. Greenslade of the entomological section and Mr. Roach, biochemist, have studied the causes underlying immunity from this pest, and found that they appear to reside in the bark and to be related to the presence or absence of some chemical substance insoluble in ether and alcohol but slightly soluble, after prolonged boiling, in water. The Northern Spy types have been crossed with other stocks and those of the progeny showing immunity—about one-third of the crosses—are tested for pomological qualities. A limited number have passed through preliminary testing and are now undergoing field trials. Work is also in progress with a view to combining scion resistance to woolly aphis with high fruit quality.

In pears Mr. Tydeman is studying a series of "wilding" pears and quinces from seed obtained from the Caucasus and Turkestan in the hope of obtaining new stocks for pears that will be hardier and more resistant to disease than those now in use. With Mr. N. H. Grubb he is carrying out a study of the factors responsible for the poor "set" of fruit in certain varieties, such as Doyenne du Comice. This involves a study of the methods of pollination in pears. Cross-bred plum root-stocks and seedlings of wild parents obtained from Asia Minor and the Caucasus through the John Innes Institution under the name *Prunus divaricata* have been tested as stocks for plum varieties. Mr. Grubb is carrying on the breeding of raspberries mainly to determine the reaction to mosaic and other diseases and pests of new varieties from crosses of existing English varieties and between these and American varieties. The strawberry work also is mainly with a view to disease resistance; seedlings bred at the Cambridge Horticultural Research Station and the John Innes Institution show striking evidence of differences in reaction to the yellow-edge virus disease.

A limited amount of work in the breeding of new varieties of apples, pears, currants and strawberries for improved yield and quality is also in progress; in general the Sub-Committee thought that this work was rightly limited in scope owing to the plethora of varieties already available and the number of new seedlings of better known genetic constitution coming forward from the John Innes Horticultural Institution; they considered that breeding for specific purposes such as resistance to diseases and pests was the most fruitful line to follow.

The Experimental and Research Station, Cheshunt.

The Experimental and Research Station of the Nursery and Market Garden Industries' Development Society, Ltd., is situated in the most important centre for glasshouse cultivation in the country, the Lea Valley. Its current programme of work covers experiments and research on the growing under glasshouse conditions of tomatoes, cucumbers, chrysanthemums, carnations, and lettuce; on early vegetables and salads in frames; on mushroom cultivation; and on the diseases of roses. The work includes manurial experiments and chemical studies of glasshouse soils; physiological problems of glasshouse crops; breeding improved varieties by hybridisation and selection; bacterial, fungal and virus diseases and insect pests of the crops grown; soil sterilisation and investigations of insecticides and fungicides, heating and ventilation of the houses; crop management; and methods of packing the produce. Besides the Director, Dr. W. F. Bewley, there are seven graded officers on the staff, and one ungraded scientific assistant who is engaged in work on flower diseases. The grant from the Development Fund sanctioned for 1936-7 was £7,370, in addition to which it was estimated that contributions from outside sources and sales of produce would amount, after an allocation towards the reduction of the Loan Account, to £2,285.

No special review of the work of the Station was undertaken by the Agricultural Research Council during the period covered by this Report. The Station was visited by a Sub-Committee in 1934 and their recommendations, which included some increases in the graded and ungraded staffs and the stabilisation of the work on virus diseases and the investigations of insecticides and fungicides, were approved by the Council and have since been carried out.

A new development, which received the support of the Council, was the study of the cultivation of mushrooms and the control of their diseases and pests, a subject to which Dr. Bewley had already given attention before special facilities for experimental work were provided at the Station. Work was started in a newly constructed modern type of mushroom shed in April, 1936. The first experiments were on the types of soil used for casing the beds and the effect of the admixture with the soil of stones and peat in different proportions. Of particular significance has been the discovery that the production of mushrooms from a given bed can be renewed by replacing the outer soil coating with a new compost of lower pH value. These experiments have already given valuable information and the work is developing on promising lines.

The extension of interest in the growing of flowers for the market noticeable in recent years has been reflected at the Station. Besides chrysanthemums and carnations, work has been done on cyclamens, heaths, arum lilies, and several other flowers. Support for the work on rose diseases is obtained from the National Rose Society, and further development of the Station's activities to cover work on the cultivation, diseases and pests of other flowers grown for the market has been urged from time to time. The Council and the Departments of Agriculture have set up a Joint Committee to consider the whole question of research affecting vegetables and flowers in Great Britain, and this Committee is engaged in a detailed examination of the present position of such research and its future organisation. From figures supplied to the Committee it appears that the estimated value of flowers raised under glass in 1931 was £2,290,000, a rise of nearly £1,000,000 over the similar estimate made in 1925. The value of the flowers and nursery stock raised in the open was estimated in the 1931 Census at £1,550,000 and the area of open land now devoted to market flowers and bulbs exceeds 12,000 acres in England and Wales, while a considerable proportion of the 3,250 acres or more under glass also grows flowers either alone or supplementary to tomatoes and the like.

The main work at Cheshunt deals with tomatoes and cucumbers. On both these crops very important progress has been made, covering amongst others such diverse subjects as the effect of manures on the cucumber (which was found to have been adversely affected in quality by phosphate deficiency), the effect of artificial light on cucumbers and tomatoes (still in progress), the control of mosaic by the use of clean seed and early roguing out of diseased plants, the renovation of exhausted glasshouse soils by the addition of straw and other plant material, the use of peat in tomato houses, the value of heating the soil to various temperatures, breeding for yield, quality and the control of tomato leaf mould (*Cladosporium fulvum*), improvement in the quality of the produce marketed, especially in preventing various blemishes on the fruit, and the promotion of early ripening in tomatoes by confining the root system in pots or boxes. The plants grown in pots were earlier in ripening and of better quality than those grown in cardboard boxes but both were superior to those grown normally in the ground. Important advances have also been made in the control of glasshouse insects, soil sterilization and various problems connected with the cultivation of flowers under glass. Seed of the Cheshunt-bred winter lettuce, Cheshunt Early Giant, for producing a crop at Christmas and at the end of February, has been widely distributed and has satisfied a long-felt need. Cheshunt Early Ball lettuce, also bred at the Station, has proved a valuable variety for frame growing. Certain aspects of the work are carried out in close co-operation with Rothamsted and the Imperial College of Science and Technology.

The Station has gained to an exceptional degree the confidence and support of growers, not only in the Lea Valley but throughout the country. It receives subscriptions from some 500 growers and the pressure on its staff for advice and guidance is heavy. It is playing a considerable, and in some cases a leading part in the important developments in glasshouse cultivation that are going on, and the demands from growers for assistance are rapidly increasing. The strengthening of the permanent staff, carried out in accordance with the Council's recommendations, will help to maintain the high level of the service which the Station is rendering to the industry.

BOTANICAL WORK AT ROTHAMSTED EXPERIMENTAL STATION.

The Botanical Laboratory at Rothamsted is under the charge of Dr. Winifred Brenchley. The Council received and adopted a Report of a visiting Sub-Committee on this and other Departments of the Station in April, 1936. The work in progress consists in a study of the effect on plants of elements occurring normally in small quantities in the soil such as nickel, cobalt, copper and molybdenum; botanical analyses year by year of the composition of meadows under long continued manurial treatment of different kinds; similar analyses of the sward from known seed mixtures; the resistance of plants to certain poisons and the conditions affecting toxicity such as concentration of the poison, stage of development of the plant and individual variations in reaction to the poison within a species; the weed seed population of the soil and the effect on weed seed germination of cultivation and fallowing.

Dr. Brenchley has charge of the water culture and pot culture experiments, many of which are designed to study some question raised in another department. Thus, the study of the effects of molybdenum was suggested largely by the observations of the workers on virus diseases at the Station that this element produced effects within the plant cells simulating those caused by certain types of virus infection. Another series of water culture experiments showed the effects of potash applied at different stages of growth and links with the work on plant physiology of the staff of the Imperial College working at Rothamsted.

Miss Warrington's and Dr. Brenchley's work on boron in plant life is well known. The increasing economic importance of this element as a controlling factor in various crop disorders has led to the carrying on of further experiments to test its effects on such crops as onions and carrots. An outbreak of heart rot of sugar beet at the Station in 1935 led to experiments in which unaffected beets as well as plants showing slight and severe symptoms were transplanted into pot culture in sand and the effect of adding boric acid compared with growth in sand without such addition. Where no boric acid was given the characteristic signs of boron deficiency developed even in the healthy plants. Boric acid treatment resulted in the production of healthy shoots in all plants that survived transplanting.

The grassland studies have shown sharp differences in the botanical composition resulting from long continued manurial treatment in the permanent plots, but they also show that within the broad outlines the composition of the herbage in a given series of plots varies greatly from year to year as a result of seasonal factors such as heavy frost. The influence of such factors also varies according to the manurial treatment, liming, the use of ammonium salts, organic manuring, and the like. In the studies of seeds mixtures, seasonal effects under the more uniform nutritional conditions of the plots have been in general the same throughout the field. Cocksfoot has tended to diminish on all the plots and ryegrass, if sown as the chief constituent of a mixture, assumes and maintains dominance. Fescue has not maintained itself well, while wild white clover is the only leguminous plant that has proved to be persistent.

The studies of the action of plant poisons has developed from the desire to test the possible application to grassland of the chemical methods of weed control employed under arable conditions. Work with thiocyanates showed that some of these had a differential effect on weeds as compared with grass, a solution of 5 per cent. ammonium thiocyanate killing many weeds and preventing others from flowering, while the grass flourished. But the effect is very dependent on weather conditions and a wet season may undo much of the work; the underground parts of perennial grassland weeds are not sufficiently injured to prevent regrowth under rainy conditions.

Work recently undertaken includes a study of the value of calcium as compared with magnesium in encouraging growth on acid soils and the effect of X-ray treatment of seeds on the ultimate growth of the plant.

THE BRITISH MUSEUM (NATURAL HISTORY), SOUTH KENSINGTON.

In pursuance of their policy of surveying all the agencies engaged in the study of, or research into any branch of applied science affecting agriculture in Great Britain, the Plants and Soils Committees appointed in 1936 a small Sub-Committee to visit the Natural History Museum at South Kensington. This Sub-Committee drew up a note describing briefly certain aspects of the work of the Museum, which was received by the Council in July, 1937.

The work of interest to the Council is mainly in the Departments of Entomology and Botany of the Museum. Normally, as was explained to the visitors by the Director of the Museum, Dr. Tate Regan, applied problems are not a direct concern of the Museum, but there were cases in which knowledge not available elsewhere was possessed by the staff, or special circumstances led to the aid of the Museum authorities being solicited in some question of applied science, and this aid, when available, was freely given.

In the entomological department, the vast collections, stated to be the largest in the world, are consulted alike by the economic entomologist who wishes to make an exact determination of the insects injurious to crops which he is endeavouring to control, and by the general body of entomologists interested in insects as a scientific study, or even as a hobby. The staff of whole- and part-time entomologists at the Museum engage in systematic studies of particular groups and are often in a position to render aid of critical importance to those who have to deal with insects as agents of crop destruction, or otherwise inimical to man. The most interesting cases of this kind seen during the visit dealt with insects injurious to tropical crops, the knowledge of which is naturally less advanced than that of the insects of temperate countries. But work on the warble and bot flies, which was demonstrated, was of evident value to British interests.

The Museum gives hospitality to the Director and scientific staff of the Imperial Institute of Entomology, an institution in which the home Governments are associated with those of the other parts of the Empire in the furtherance of applied entomological work. Towards this work, most of which is of direct agricultural importance, the Museum staff and collections render valuable service.

In the Botanical Department the systematic study and classification of plants is again the dominant activity, and here also there are vast collections of authentically named specimens and a considerable staff who engage in taxonomic and floristic research. In the mycological section of the Department laboratory work is carried on, and the applied significance of the work was especially evident. Studies were in progress on the fungi causing human diseases, moulds used in cheese making and various industrial fermentation processes, fungi used to stimulate the germination and promote the growth of orchid seeds and seedlings, fungi employed in the preparation of various fermented beverages (ginger beer, tea cider, koumiss) and the cultivation and identification of fungi injurious to plants and plant products. The Keeper of the Department, Mr. J. Ramsbottom, stated that he received many enquiries of an applied nature regarding the uses of plants, injurious and beneficial fungi and the like. Where these could be readily dealt with within the Department they were answered direct. Otherwise they were referred to the appropriate institution elsewhere. The main function of the Department, however, was the identification of plants and the maintenance of collections available for study by botanical workers.

THE NORFOLK AGRICULTURAL STATION, SPROWSTON.

Grants are made from the Development Fund in aid of the work at the Norfolk Agricultural Station. The Development Commissioners had expressed a desire that the Agricultural Research Council should review its activities, which include field experiments of considerable agricultural importance. The Plants and Soils Committees accordingly appointed a Sub-Committee which visited the Station in August, 1937, and submitted to the Committees a note on their visit.

Perhaps the most interesting feature of the Station is the close association maintained between the Norfolk County agricultural and horticultural staff engaged in educational work and demonstation on the one hand and the staff of the Station itself, engaged in field experiments, on the other. Mr. Rayns, the Director of the Station, is also Director of agricultural education for the county, and recently the County horticultural staff have also been placed under his control; all the county agricultural and horticultural officers are now working under unified direction. The Station has extended its demonstrational and advisory activities and appoints two members of the Norfolk County Council to its Executive Committee. In fact, for administrative purposes, the County and Station staffs may be regarded as one, though separately financed. The work also has become so closely interconnected that it is difficult to separate it into two parts. At the same time the Station preserves its autonomy as an institution administered by and for Norfolk farmers and landowners on a voluntary basis. The Station staff aim at linking the lectures and demonstrations throughout the county with the experiments on the farm; the Sub-Committee were informed that it was easy to find farmers to co-operate in arranging simple field trials and demonstrations (as, for instance, in the use of boron for the control of heart rot of beet) from among the 700 subscribers to the Society. Most of the county staff had been trained at the Station and those who were stationed elsewhere, as at King's Lynn in the western part of the county, maintained close contact with their colleagues at Sprowston.

The Station is the chief centre of experimental work on sugar beet (other than disease control) in Great Britain. It receives grants for this purpose through the Sugar Commission and, in regard to varietal trials carried out in co-operation with the National Institute of Agricultural Botany, from the Ministry of Agriculture's Crop Variety Testing Scheme. The Station has also accepted responsibility for the inspection of the beet seed crops grown in England under the aegis of the British Sugar Beet Producers' Association, which gives a grant for the purpose.

Numerous experiments in sugar beet cultivation were seen by the Sub-Committee. They included rotation and fertiliser experiments; the use of beet tops as an organic manure; spacing trials, which indicated an optimum spacing of 14 by 14 inch rows at right angles to one another effected by mechanical cultivation and a fairly good result from spacing 18 inches between the centre rows and 13 inches between the outer rows of a four row horse-drawn drill; tests of methods of singling, which involved leaving the strongest plant, leaving the weakest plant and leaving an average plant; tests of the time of sowing, bunching, singling and lifting; and the effect on the crop of a firm as against a loose seed bed. The use of a compactometer which gives a record of the firmness of the soil was demonstrated. In the varietal trials English grown seed was tested against the German Kleinwanzleben E, and a number of foreign strains were also under observation.

A series of experiments to investigate various methods of disposal of beet tops and straw is carried out under a grant from the Royal Agricultural Society of England. They include the spreading of straw on the young seeds in hay mixtures, the relative value of straw and farmyard manure for sugar beet, and the use of beet tops with and without straw on barley.

The Station also co-operates with the Horticultural Research Station, Cambridge, and the Norfolk Seeds Association, in the growing of improved strains of Brussels sprouts bred at Cambridge and reselected at Sprowston by the Cambridge workers. Barley seed from stocks rogued at the Station is grown on for multiplication by members of the Society. Other tests under the Crop Variety Testing Scheme are carried out with winter wheats, winter and spring oats, mangolds and kale.

In a test of selected commercial strains of late flowering red clover in 1936 a severe attack of clover sickness occurred and enabled observations of varietal differences in reaction to this disease to be made.

The Sub-Committee formed a very good opinion of the work in progress at Sprowston. They reported that the farm is being fully utilized and that the experiments were well planned and managed so as to test methods of special importance to Norfolk farmers.

MISCELLANEOUS.

Use of chlorates as weed killers.

On the recommendation of the Agricultural Research Council a small grant was made from the Development Fund during the academic year 1935-6 to the North of Scotland Agricultural College in aid of an investigation of the efficacy of certain chlorates as weed killers. This was extended into the following year as the full amount was not expended in 1935-6.

It was found that the concentration and quantity of the chlorate required to kill different kinds of weeds varied considerably, so that it was necessary to determine dosages for individual species of weeds. The group selected for testing included a number of the more important perennial and annual weeds of pastures and cropped land. Sodium chlorate proved to be preferable to potassium chlorate as being cheaper, more soluble and less liable to " cake ". There was no appreciable difference in toxicity between the two salts. October was found to be the best time of application, especially for perennials; heavy dressings in December injured turnips sown the following May, but September dressings of equal strength caused no damage to the succeeding turnip crop. Potatoes and cereals were found to be more tolerant of chlorate than turnips.

Fairly effective weed control was obtained in most cases, the efficacy being proportionate to the concentration, from 15 per cent. downwards. Lower strengths are successful if there is enough water to wet the leaves thoroughly and carry the poison down to the underground parts of perennials. In grassland the more vigorous the herbage surrounding the weeds, the less effective is the weed toxicity: it is easier to kill thistles on fallow or stubble than in pasture. Ploughing helps the destruction of perennial weeds the foliage of which has died down.

Tests were also carried out with sulphuric acid and copper sulphate on an oat crop heavily infested with hemp nettle (*Galeopsis*), knotgrass (*Polygonum*), spurrey (*Spergula*) and poppies. Sulphuric acid was the more effective, but even at 15 per cent. concentration did not give complete control of poppies. A concentration of 7·5 per cent. was adequate against the other three weeds but 10 per cent. gave better results and seems to be a good general dressing, causing only temporary damage to the crop.

Chemical reactions of potato tubers.

A grant of £200 was made from the Development Fund to the Edinburgh and East of Scotland College of Agriculture, on the recommendation of the Agricultural Research Council, for work during the academic year 1935-6 on the chemical reactions of potato tubers as a means for characterising different types and recognising the presence of certain diseases and disorders in the tubers. This was continued by a grant of the same amount from the funds at the Council's disposal during the academic year 1936-7.

During the first year the oxidation-reduction potential of the tubers was studied by Dr. A. M. Smith and Mr. W. Y. Paterson, and a rapid method of determining the quantities of reducing material present was devised. Significant differences were found to exist between normal tubers of different commonly grown varieties such as Eclipse and Majestic, Arran Pilot and Sharpe's Express, and so on; more important was the fact that tubers presumed healthy could be separated from those known to be infected by virus disease. A rapid diagnostic method for virus infection which, however, had only a limited application, was a quantitative test for ascorbic acid; infected tubers contain more of this acid than the healthy ones. It seems possible that "sprain" may also be detected by similar means.

Further work was directed to the study of various constituents of the tuber, apart from starch, and of the influence of environmental conditions in modifying the chemical nature of the tuber contents.

The biology and habits of slugs attacking the potato crop.

In 1934 a study of the biology and habits of slugs that damage potatoes was commenced at the Edinburgh and East of Scotland College under a grant of £200 for the academic year made from the Development Fund on the recommendation of the Agricultural Research Council. This grant was renewed in the following year, and in 1936-7 the investigation was continued with a grant at the same rate from the funds at the Council's disposal. Slugs were stated to be by far the most serious potato pest in the area with which the College is concerned and to destroy one-seventh or one-eighth of the crop harvested.

Mr. R. Carrick was employed on the investigation until 1936 when he was succeeded by Mr. W. J. Esslemont; both worked under the general direction of Dr. A. E. Cameron.

The first step was to identify the species injuring the tubers and their prevalence in different situations. Work was mainly concentrated on the gray field slug (*Agriolimax agrestis*), which was bred and studied under laboratory conditions. This slug was found to attack potato tubers only in the absence of fresh green food but attractant poison baits proved useless. Copper sulphate was the best of the contact poisons tested but spraying must be done at night owing to the nocturnal habits of the slugs. Further work traced the life history from the egg to full maturity, the average number of eggs laid, their period of incubation, and the effect of seasonal conditions on fluctuations in the numbers of slugs in the field. The subterranean habit of the slugs made the application of poisons by spraying difficult; their above-ground activities, however, depend on such factors as humidity and this may be of importance in using contact poisons.

In 1936-7 trials of metaldehyde showed that this compound is the most promising poison tested up to date. It is effective when used either as a poison bait mixed with bran, or as a soil fumigant. Nothing appears to be known as to the nature of the toxic action of metaldehyde and a study of this is proposed. Some laboratory work on the toxicity of derris to slugs has been carried out but more extensive tests of this and other substances under field conditions are required. In recommending the continuation of the grant for a fourth and final year the Plants and Soils Committees suggested that the question of cost of preventive or control measures in relation to the amount of damage caused in different circumstances should be taken into consideration.

Research on the storage of seeds, bulbs and roots for export.

Arising from a request by the Metal Box Company, Ltd., for information on the preservation by packing in air-tight tins of seeds, bulbs and roots destined for export a conference was held in the Council's office in December, 1936. This was attended by representatives of the trade and of the Government Departments concerned.

It was reported at the conference that losses in germination of seeds are fairly rapid in certain cases, particularly the Brassicae, under the usual methods of packing and storage in transit. Cold storage would be effective in preventing this, but it is difficult or impracticable with small packages and might be valueless unless there were a complementary system of cold storage at the place of destination. Certain American firms are packing seeds in vacuum-sealed glass tubes with a guarantee of germination. It was suggested that the difficulties met with from loss of germination, premature germination, mould fungi, and the like might be overcome by packing in air-tight tins containing inert gases, but research would be necessary before the best method could be worked out. As regards bulbs, the advisability of enclosing these in non-ventilated containers was considered to be doubtful, as experience indicated that bulbs travelled best when free ventilation was provided.

The meeting favoured the initiation of research if funds could be secured, but it has since appeared to be improbable that the interests concerned are sufficient to enable contributions to be expected at the present time. Even in the case of seeds, it appears to be more a question of attention to the condition of the seeds when packed and the way they are packed than of the exclusion of air or storage under special conditions.

V.—PLANT PROTECTION: ENTOMOLOGY, MYCOLOGY AND HELMINTHOLOGY

Two specialist Committees of the Agricultural Research Council co-ordinate and supervise work in two branches of the science of plant protection which require the collaboration of entomologists and mycologists with help from chemists, physicists and plant physiologists. They are the Committees on the Virus Diseases of Plants and on Insecticides and Fungicides.

VIRUS DISEASES OF PLANTS.

The Sub-Committee on the virus diseases of plants mentioned in the Council's last Report was continued to co-ordinate work in progress in this field in Great Britain and was enlarged by the addition of two new members during the period under review. The Virus Diseases of Plants Committee presented a Report to the Council in the autumn of 1937.

Special interest in the virus diseases of plants in this country was first aroused about the year 1920; complaints concerning the increasing prevalence of " curl " had for some time previously been coming in to the Ministry of Agriculture's Plant Disease Survey and it seemed likely that curl was the same as the communicable disease termed leaf roll or phloem necrosis in other countries. At about the same time it was realized that a loosely defined affection of potatoes, up to then known as " mottling ", " miffiness " or by other local names, was, in all probability, the disease which in the United States and Canada was known as potato mosaic. Stripe and mosaic of the tomato had also been recognized but the former was then thought to be of bacterial origin; it is now known that both are due to viruses.

Earlier research work, done by Dutch and American plant pathologists (some of it begun in 1913), had shown that potato leaf roll and mosaic were occasioned by so-called " filterable viruses ", a name given because of the character which they possess of being able to cause infection after passage through a bacteria-proof filter. By 1921 the infectious nature of these diseases had been confirmed at the Ministry's Plant Pathological Laboratory, and trials were being organised to demonstrate the necessity of using virus-free " seed ". At about this time, a study was begun of insect transmission of these diseases at Manchester University.

In February, 1924, the Ministry of Agriculture called a Conference of those interested in or working on virus diseases of plants. It was by then obvious that special provision of men and money was needed for the more vigorous prosecution of research in this new field of plant pathology. As a result of the Conference a Virus Diseases of Plants Committee was formed to review the situation and recommend a programme of investigation covering fundamental research and subsidiary work of an economic nature, and to secure the co-ordination of that part of the programme suitable for financial aid from the Ministry. By the summer of 1925 research work on fundamental virus disease problems was in progress at Rothamsted and Cheshunt; on the economic importance of potato leaf roll at Bangor; on insect transmission of virus diseases at Manchester; on hop mosaic and that of raspberries at East Malling; and on the part played by virus diseases in the degeneration or " running out " of potato stocks at the Imperial College of Science, London. The prosecution of all this work was made possible by special research financial aid provided through the Ministry of Agriculture.. Meetings of the Committee and of the investigators were arranged twice annually, when results could be announced, plans for further work discussed, co-operation secured and overlap avoided.

The economic problems caused by the diseases were considered at great length by the Committee. They are most serious in the potato crop and proposals for dealing with the potato virus problem, the essence of which was to secure the production of healthy " seed " potatoes under official auspices, were submitted to the Ministry. These were not found practicable and it was then decided that work on the economic aspects of the potato virus disease problem should be carried on at Cambridge, the staff at the School of Agriculture there being strengthened for the purpose.

In June, 1927, the whole virus situation was reviewed by the Development Commissioners in consultation with the Medical Research Council, and it was agreed that further aid was required for the development of investigations into the nature of plant viruses. Direct methods of securing co-operation between workers on plant and animal virus diseases were suggested.

At the Imperial Agricultural Research Conference, held in the autumn of 1927, great stress was laid upon the importance and urgency of the virus diseases of plants problems. As a result, the Ministry's Virus Diseases of Plants Committee was enlarged to include, amongst others, representatives of the Department of Agriculture for Scotland. A team of workers, under the leadership of Dr. Henderson Smith, was organized for research on the nature of viruses at Rothamsted and, generous financial aid being forthcoming from the Rockefeller Foundation, additional glasshouse and other equipment was provided there. The Potato Virus Station at Cambridge was considerably extended in equipment and staff, the Scottish Society for Research in Plant Breeding was enabled to appoint investigators to deal with the genetical aspects of virus diseases, and virus disease work generally was extended. At Bangor assistance was provided for research which led to the establishment of a scheme for the commercial production of the highest class seed potatoes (practically virus free), and this is still in operation.

Since 1930 the Ministry's Virus Diseases of Plants Committee has met annually, in conference with the research workers, at one or other of the centres at which virus research is being prosecuted. Recently, however, it has been proposed that this Conference should in future be organized by the Council's Sub-Committee on the Virus Diseases of Plants, the activities of which have been referred to in previous Reports of the Agricultural Research Council.

In the following paragraphs summaries of, and observations on, the work at the various centres are given.

Rothamsted Experimental Station.

Dr. J. Henderson Smith is the leader of a team of workers organized in 1928 to investigate the fundamental nature of viruses in the Department of Plant Pathology, Rothamsted. The characters of the infective agent were at first studied in the expressed sap of an affected plant, the yellow or aucuba mosaic of the tomato being that on which most of the earlier work was based. It was not known whether a virus exists as a diffuse liquid in the sap or in particulate form but, by employing special methods of filtration, dilution and inoculation, it was definitely proved that the virus is particulate, and the sizes of the particles, which vary with different viruses, have been estimated.

The plant viruses hitherto studied can only increase and multiply in the living cells of the host plant. All attempts to cultivate them artificially on a non-living substratum have failed. Within the affected cells some viruses induce the formation of intracellular, or " X " bodies, and some workers maintained that these " X " bodies were organisms and represented the causal agent of the disease. Rothamsted work, however, has shown exactly how these intracellular bodies arise in the form of coagulated and precipitated by-products of the cytoplasm, and the process has been photographed cinematographically. It has also been found possible to induce the formation of analogous bodies by the introduction of cytoplasmic coagulants, such as molybdenum compounds, into healthy plants.

It has been demonstrated that a virus can ordinarily only enter the plant through ruptured living cells and, once in the plant, cannot travel across dead cells but moves along the protoplasmic strands of living tissue. In green tissues the virus inhibits the formation of chlorophyll corpuscles and adversely affects the respiration of the plant. In *Datura* and *Lycium* the virus and its effects are strictly localised to regions around the point inoculated and the use of this " local lesion " technique with certain hosts has proved of great advantage in quantitative measurements of virus concentration, and in studies of the particulate nature of plant viruses.

A great deal of pioneer work on insect transmission of viruses has been done at Rothamsted. It is generally supposed that the virus is introduced into the plant with the saliva of the insect but how the virus reaches the saliva is still unknown. The quantities of virus taken up by the insect after brief periods of feeding on the diseased plant have been estimated; they are extremely minute and it seems almost certain that the virus must multiply in the body of the insect.

Important advances in knowledge have resulted from the development of studies, originating in America, on the purification of certain plant viruses. In this work Mr. F. C. Bawden, formerly of the Cambridge Potato Virus Station and now at Rothamsted, has collaborated with members of the Biochemical, Pathological and Crystallographic Laboratories in Cambridge. Highly purified concentrations of these viruses have proved to be nucleo-proteins of high molecular weight existing in liquid crystalline form. When sedimented from neutral solutions they form bi-refringent jellies, and when precipitated with acid or ammonium sulphate they settle as fusiform aggregations.

The visiting Committee to Rothamsted whose Report was adopted by the Council in April, 1936, did not specially consider the virus work there since, as mentioned in the last Report of the Council, it had been reviewed recently by the Committee appointed to advise on the continuation of research work previously financed from the Empire Marketing Fund, which strongly recommended that provision should be made for carrying it on. The cost of the work is provided by a special grant from the Development Fund, outside the ordinary block grant to the Station. This grant amounted to £2,440 in the academic year 1936-7.

Potato Virus Station, Cambridge.

The work of the Potato Virus Station, which was begun in 1926 with Dr. R. N. Salaman in charge, has been described summarily in the last two Reports of the Council. In the original programme great stress was laid on the importance of the investigations on means of infection by insects from potato to potato or from secondary plant hosts, and the protection of clean field crops from infection. These investigations were intended to promote the practical purpose of discovering how healthy potatoes could be grown for " seed ". Funds were secured from the Development Commission and the Empire Marketing Board which permitted of the erection and maintenance of suitable insect proof glasshouses and other buildings on a plot of land belonging to the Cambridge University Farm. Dr. Kenneth M. Smith was transferred to Cambridge from Manchester, where he had been engaged on the investigation of insect transmission of these diseases.

Methods of testing plants for the presence or absence of various virus diseases have been gradually evolved and employed and thus small stocks of a number of varieties of potatoes believed to be absolutely virus free have been accumulated. Comparative studies of insects suspected of transmitting potato virus diseases have been undertaken. The leaf roll virus and potato virus Y are transmitted by *Myzus persicae,* a species of aphis responsible for the dissemination of many virus diseases, but no insect vector of potato virus X has as yet been discovered despite prolonged search. The specific entity of several of the viruses affecting potatoes has been established and it has been proved that the symptom picture exhibited by a virus-affected potato plant may sometimes be the result of the presence simultaneously of two or more viruses. Methods for the analysis of the component elements in these cases of combined infection have been devised. Further, it has been shown that the same virus can produce different types of disease according to the particular variety of potato into which it is introduced, or it may remain present in a latent condition in a potato plant, the host thus acting as a symptomless " carrier " of disease. It has also been shown that there are degrees of virulence in strains of a single virus and that a plant inoculated with a weak strain can be rendered immune from subsequent infection with a virulent strain of the same virus.

Of recent years much of the Cambridge work has not been concerned specifically with the economic aspect of virus infection in the potato but has become of a more fundamental character and has extended to various viruses affecting tobacco, vegetables and ornamental plants. Enquiries into the nature and properties of individual viruses, their resistance to desiccation, ageing, heat, chemicals and the like, have been conducted. Serological studies, using rabbit serum as the source of antibodies, have also been carried out. A technique has been developed for a rapid and accurate means of determining the relative virus content of infective samples and of determining the total virus content in cases where the local lesion method might give misleading results. Work on the action of certain enzymes on potato virus X, especially in relation to its serological behaviour, has thrown light on the composition of the virus. Much work has been done on the size of the particles of different viruses and their passage through graded collodion filter membranes of known pore size.

The work at Cambridge has important economic implications in addition to its advancement of fundamental knowledge, especially in regard to the recognition of the different diseases caused by individual potato viruses and their combinations, their transmission, the possibilities of producing virus-free stock, and the reaction of potato varieties to infection. Whether the artificial production of immunity from severe virus infection by inoculation with strains of low virulence is capable of field application cannot yet be predicted.

Early in 1937 an application was received from the Potato Virus Station for assistance to enable Mr. W. D. MacClement to continue investigations on the relationship between the tobacco mosaic virus and a crystalline protein obtained from the sap of diseased plants, which he had commenced at the Molteno Institute of Parasitology. A grant was made by the Agricultural Research Council to the Molteno Institute of £50 with effect from the 1st April, 1937. Mr. MacClement has since been appointed to the staff of the Potato Virus Station but during his six months' tenure of the grant he worked with Dr. Kenneth

Smith on the improvements of methods of filtration and purification of several viruses under different conditions, finding that all of them become relatively unfilterable when highly purified.

The Experimental and Research Station, Cheshunt.

At the Experimental and Research Station for glasshouse crops work on virus diseases was at first carried on by the Director, Dr. W. F. Bewley, but from 1929 onward other workers collaborated and since 1934 Dr. G. C. Ainsworth has given practically his whole time to virus investigations.

The work on tomato and cucumber mosaic diseases has consisted largely of studies in symptomatology, the effects of environmental factors (including soil conditions) on symptoms, the separation and recognition of the different viruses concerned, and the effects of virus diseases on the metalbolism of affected plants. Tomato mosaic, as the term was first used, has been found to include several distinct diseases, of which three are now recognised, namely, aucuba or yellow mosaic, ordinary mosaic and enation mosaic. This last type is a disease recently described in detail and named by Dr. Ainsworth; it is due to a strain of ordinary tobacco mosaic (*Nicotiana* virus 1), very readily transmitted by mechanical means. The streak diseases in tomatoes have also been investigated in co-operation with workers at Rothamsted and in Canada, and four types identified. Three other distinct virus diseases of tomatoes have been segregated, namely, spotted wilt, fern leaf and bushy stunt.

The virus diseases of cucumbers have likewise been intensively studied and three types, yellow mottle, green mottle and yellow mosaic, separated. A study of the transmission of the virus through the seed has indicated that cucumber mosaic is transmissible in this manner and, although the percentage of seeds from an affected plant that actually transmit the disease is small, there is great potential danger from seeds from affected plants. Seed transmission has not yet been proved for tomato mosaic but there is strong circumstantial evidence in favour of it.

Some attention has been given at Cheshunt to the physiology of virus-affected plants and it has been found that the carbohydrate and nitrogen metabolism is upset. Experiments in connection with light of different colours showed that with aucuba (yellow) mosaic of the tomato, the harmful effect of the virus on the plant's efficiency increases as the intensity of the light goes up. It was also found with ordinary tomato mosaic that the symptoms varied according to the duration of daylight to which the plants were exposed and that the incubation period of the disease varied inversely with the growth rate of the plant.

The physical and other characteristics of the different viruses affecting the tomato and cucumber have been determined and their transmissibility by insects studied. Thus, at Cheshunt, as at Cambridge, both the fundamental aspects of virus research and the application of the results in practice have been taken into account. The Cheshunt work has been of great practical value to the glasshouse industry.

East Malling Research Station.

From 1921 onwards much attention has been paid at this Station to the mosaic disease of raspberries, which has been studied there by Mr. N. H. Grubb, Mr. R. V. Harris and Dr. A. M. Massee. The disease was early proved to be transmissible but, although a great deal of work has been done, the insect vector has not yet been determined with certainty; the East Malling workers are not satisfied that *Aphis rubiphila* transmits the disease there as has been claimed by other workers elsewhere. By carefully planned work over a number of years a practical and successful scheme for the elimination of raspberry mosaic has been established. It consists of the commercial development of special nurseries, devoted solely to cane production and starting with virus free nucleus material raised at East Malling. The stocks are kept under strict surveillance for the supply of healthy canes to establish new fruit plantations. Only one variety of raspberry, the Lloyd George, was dealt with in this way at first, but it has proved such a success that a start is being made with other varieties.

Extended observations and experiments carried out over a period of years by the Director of the Station, Dr. R. G. Hatton, Dr. R. C. Knight, Dr. Massee and Mr. J. Amos showed that the condition known as " reversion " in black currants is an infectious disease, transmissible by grafting but not by sap transfusion and of which the mite *Eriophyes ribis* may be a natural vector. It would thus seem that reversion is a virus disease.

Of recent years virus investigations at East Malling have concentrated mainly on the strawberry, in which Mr. Harris has made detailed and intensive studies of a serious virus disease which he has named " yellow edge ". A second virus disease, " crinkle ", was noted by the Long Ashton workers and its study has also been taken up at East Malling. In the further investigations of these diseases Dr. Massee is collaborating with

Mr. Harris. The Virus Sub-Committee visited the Station in May, 1937, and examined the important work then in progress which they considered was already leading to valuable results. They reported, however, that the equipment and facilities available were no longer adequate for the programme contemplated, and recommended the provision of a special glasshouse and an insectary and the appointment of an assistant to aid Mr. Harris and Dr. Massee in their virus work. These recommendations were endorsed by the Council.

Long Ashton Research Station.

The Sub-Committee whose visit is referred to in greater detail on p. 98 saw the work on virus diseases of vegetables in progress under Mr. L. Ogilvie at this Station in 1935. The work was chiefly on lettuce mosaic, a disease that is very prevalent in the Bristol province. Studies have been made of varietal susceptibility, and resistant varieties have been found which have replaced some of the very susceptible ones hitherto used. Lettuce mosaic is seed transmissible to a very high degree and it appears that the real remedy lies in the production of lettuce seed under strictly controlled conditions from only virus-free plants, with the elimination of susceptible weeds from the neighbourhood of the crop. In addition to this some research has been done on hop virus diseases, strawberry " crinkle ", tomato spotted wilt and, more recently, a mosaic disease of dwarf beans has been recognised.

University College of North Wales, Bangor.

Dr. T. Whitehead has been in charge of the virus disease investigations at the University College of North Wales since 1921. Having observed that in parts of North Wales some varieties of potatoes had been grown without change of seed and without degenerating for long periods, trials were carried out which showed that seed potatoes could be raised in certain of these localities which were as free from virus as the best stock seed obtainable from Scotland. This work was steadily developed during subsequent years and has culminated in the formation of an Association of growers for the commercial production of high grade seed potatoes in North Wales. Leaf roll has been the subject of a great deal of work, including chemical and physiological studies, at this centre. A recent study of the " carrier " problem suggest that, as far as potatoes are concerned, " carriers " do not appear to be in reality such a menace as has sometimes been supposed.

Dr. W. Maldwyn Davies, whose death in February, 1937, was a great loss to virus disease research, did much work at this centre in collaboration with Dr. Whitehead on the problem of aphis transmission of virus diseases. He attempted with considerable success to correlate aphis migration to, and aphis population within the crop with the spread or absence of spread in it of virus diseases, and studied the factors affecting the migration of *Myzus persicae*, finding that cool, damp, windy localities are unfavourable to its spread. The initial infestation of the potato crop comes from wingless forms living and multiplying during the winter on various Brassicae and migrating to the potato crops when winged forms are produced in the early summer. In 1936, Dr. Davies carried out a preliminary survey of the eastern parts of Scotland, the results of which suggest that the migration of aphides in Scotland is governed by the same meteorological factors as in North Wales. In the part of Scotland studied the direction of migration was from west to east instead of from east to west as in Wales.

In 1936, the slight expenditure required, mainly for travelling, to enable Dr. Davies to undertake this work in addition to his ordinary duties as an advisory officer was transferred from the funds on the Ministry's Vote for experiments of a practical nature not drawn from the Development Fund to the grants for special researches which the Agricultural Research Council decide to assist. The Council approved grants amounting in all to £100 for this work from April, 1936, to March, 1938.

Scottish Society for Research in Plant Breeding.

The virus work carried on by this Society is directed primarily towards an analysis of the inheritance in potato varieties of different degrees of susceptibility to virus diseases, with the ultimate object of the discovery or breeding of varieties immune from, or resistant to, virus attack. It is at present carried on by Mr. G. Cockerham and Mr. C. A. Lyall. When virus work at the Huntley Sub-Station in Aberdeenshire was terminated, as mentioned in the Council's last Report, it was transferred to the headquarters' station at Corstorphine and the Ainville Sub-Station. Studies have been undertaken on the transmission of virus through sexually formed seed, on the qualitative and quantitative effects of virus diseases on the reproductive organs, and on the nature and causes of degeneracy, both hereditary and induced, in seedlings and progenies. Crosses between healthy and virus infected plants are difficult to obtain owing to degeneration or imperfect formation of pollen in the latter. When such crosses are obtained the seedlings may show types of abnormality simulating those exhibited by virus diseased plants, e.g., leaf roll. Such abnormalities are not transmissible like virus diseases.

Another line of investigation is the study of resistance and susceptibility of potato varieties to individual virus diseases, and the mode of inheritance of these reactions. Reaction to some of the common viruses has been found to be an heritable character capable of genetic analysis so that resistance should be obtainable by selective breeding. Ecological studies on aphis populations have recently been started to aid in the field studies on resistance and susceptibility. The earlier biochemical and physiological work on carbohydrate and nitrogen metabolism in healthy and diseased plants has been terminated except for some subsidiary investigations which it is hoped may lead to the development of a method for the rapid estimation of the presence or absence of viruses in potato tissue.

The Scottish Seed Testing and Plant Registration Station, Corstorphine.

Since 1929 a scheme has been in operation at this Station under the direction of Mr. T. Anderson for the building up of healthy stocks of potatoes. Selected healthy plant "units" were grown in isolation for two years and any showing traces of disease eliminated. The remaining healthy units were then bulked and the resulting stock grown under ordinary conditions. During later years much glasshouse work has been done on the analysis of symptom complexes presented by plants selected from the field. Susceptibility tests of new seedlings submitted for the Registration trials have been made by classifying them with plants known to contain certain potato viruses and virus combinations. Special investigations are in progress with some varieties showing marked variation in size and also with potatoes that show the abnormal conditions known as "wilding" and "bolter" to determine if these may be connected with virus infection. Yield and maturity trials are being made to ascertain the effects caused by the different grades of mosaic. An attempt is also being made to discover the reason for the increasing prevalence of net necrosis in the variety Golden Wonder, in which it appears to have some connection with leaf roll.

The work at the two Scottish Stations at Corstorphine has its chief value in that it is directed to maintain the high reputation gained by Scottish seed potatoes. To do this, more and more attention will have to be given to seed production under conditions which inhibit infection with virus diseases. It seems to be quite clear that, as in other areas, virus diseases have increased in prevalence in Scotland during recent years.

South Eastern Agricultural College, Wye.

In the past a great deal of work has been done on the virus diseases of hops by Professor E. S. Salmon at the South-Eastern Agricultural College, Wye. Several diseases of the virus type have been studied and much attention has been given to the occurrence of symptomless carriers of mosaic and other virus diseases of hops and to varietal susceptibility to these diseases. While the Fuggles variety is immune from the common hop mosaic, another virus disease, " nettlehead ", is becoming increasingly prevalent in this variety. Fuggles are also subject to other virus diseases, including a new one first seen in 1934. Extensive studies of varietal resistance to these diseases are in progress. The new variety Brewers' Favourite, for instance, has not shown susceptibility to nettlehead and is in other respects superior to Fuggles; it can replace the latter where nettlehead is severe. For the last five years Professor Salmon has done little experimental work on hop virus diseases at Wye, lest the new seedlings, that are being raised there, in the hope of securing superior varieties of hops for brewing, might become attacked. Recently representations have been made to the Agricultural Research Council stressing the growing urgency of the hop virus disease problem especially in Worcestershire and Herefordshire, and emphasising the necessity for some special provision for a study of this problem.

University College, Exeter.

At the University College of the South-West of England Dr. J. Caldwell, formerly a member of the virus team at Rothamsted, has commenced work on the virus diseases of certain horticultural crops aided by a grant from the Agricultural Research Council of £455 for the year from the 1st February, 1937. With this grant Mr. A. L. James was appointed to assist Dr. Caldwell and work was commenced on the " stripe " group of narcissus diseases which are believed to be due to virus infection. Four main types of symptoms occur, the commonest of which resembles the ordinary mosaics of other plants. In another form the mottling is grey rather than yellowish-green, while the other two cause abnormalities in the anatomy of the leaves and flower stalks. Attempts to transmit these diseases are in progress. Some work has also been done on manuring and the treatment of diseased bulbs and on the influence of temperature and other external conditions on the course of the diseases. In addition, work on possible virus diseases of iris, anemone, chrysanthemum and broccoli has been commenced.

INSECTICIDES AND FUNGICIDES.

As described in the last Report of the Agricultural Research Council a Sub-Committee was appointed by the Plants and Soils Committees of the Council to consider the position of insecticidal and fungicidal investigations in Great Britain. This Sub-Committee, which reported in 1934, recommended the development of work on insecticides and fungicides intended for the control of the pests and diseases of fruit crops. They considered that the work on insecticides then in progress at Rothamsted and that on glasshouse fumigants, soil sterilization and the like in progress or contemplated at Cheshunt, should form part of the normal activities of these stations. The subject of soil disinfection other than by heat was considered but the immediate development of research on this difficult problem was not recommended owing to the narrow resources available. The Sub-Committee was maintained in being to co-ordinate the investigations at the various research centres and in 1936 was reconstituted as a technical Committee on which those actively engaged in research in this subject were represented.

During the period under review two important developments in the field covered by the Council's Committee on Insecticides and Fungicides occurred. New lines of investigation of the use of soil fumigants as insecticides were indicated by work undertaken by Mr. A. G. Pollard at the Imperial College of Science and Technology and by work with the same object but a different line of approach by Mr. W. R. S. Ladell at Rothamsted; and a study of the physiological reactions of insects to toxic gases and other insecticides, a field in which relatively little investigation had been carried out, became possible in Professor J. W. Munro's Department of the Imperial College. The Council decided to aid both these aspects of research and made grants to the Imperial College and Rothamsted for the purpose. Reports on these and the other investigations in progress on insecticides and fungicides are given in subsequent pages.

Rothamsted Experimental Station.

Dr. F. Tattersfield has continued the studies of insecticides of vegetable origin on which he has been engaged for a number of years. An experiment on the effect of manuring and liming on pyrethrum plants in light sandy soil has been carried on since 1933 and has shown that it is possible to obtain good crops on such land for four years. Experiments on the artificial drying of the flowers have been carried out in conjunction with Mr. S. G. Jary, the advisory entomologist at Wye Agricultural College; they showed that drying at 52° C. for 10 hours and 60° C. for 6½ hours had no deleterious effect on the pyrethrin content, but higher temperatures, e.g., 68° C. for 5¾ hours, reduced the percentage of pyrethrin. A colourless potent extract of pyrethrum has been prepared by Dr. J. T. Martin of Dr. Tattersfield's department in conjunction with Dr. C. Potter of the Imperial College of Science and Technology.

Much work has been done on the evaluation of *Derris* root for potency as an insecticide. Rotenone is the most toxic active principle so far isolated but does not account for the whole of the activity. In comparing the value of a number of samples of differing types of *Derris* root from Malaya and elsewhere none of the analytical methods so far proposed was found to be completely accurate in giving a measure of insecticidal potency. A fuller investigation was, therefore, made with a view to differentiate the varieties by chemical means. The results indicated that while *Derris elliptica* is practically free from toxicarol, *D. malaccensis* and a Sumatra variety of the root contained much of this derivative. A study of the optical rotations of the resins showed that the behaviour of *D. elliptica* differed from the other two which were closely related, the difference being due to the toxicarol-containing fraction. An optically active crystalline compound showing the rotatory changes characteristic of the *D. malaccensis* type resins was isolated from the latter and may be a precursor of toxicarol. It was markedly more toxic to insects than toxicarol itself though not so potent as rotenone. In regard to the methods in current use for the determination of the rotenone content of the root comparative tests in a number of laboratories, in which Rothamsted co-operated, showed that a standardised method of analysis is much needed.

Various other plants used as fish poisons in tropical countries have been also under study for their insecticidal value. They include *Mundulea suberosa* leaves and bark, *Dolichos pseudo-pachyrhizus, Tephrosia macropoda, T. vogelii, Milletia pachycarpa* and *Triptergium wilfordii.* All but the last were insecticidal, but none as toxic weight for weight as good samples of *Derris elliptica* or *D. malaccensis.*

In order to intensify the work on these vegetable insecticides the Agricultural Research Council, in consultation with the Ministry of Agriculture and Fisheries and the Colonial Advisory Council for Agriculture, recommended the provision of additional funds jointly from the Ministry and the Colonial Development Fund. A joint contribution of £1,000 a year (£600 from the Ministry and £400 from the Colonial Development Fund) has been approved for three years to provide further chemical and entomological assistance for this purpose to the Insecticides and Fungicides Department at Rothamsted.

In 1935 Mr. W. R. S. Ladell commenced a study at Rothamsted of the methods by which soil insecticides could be tested against wireworms, eelworms and similar soil inhabiting pests. The investigation was financed by a grant from Messrs. Imperial Chemical Industries, Ltd., and at first included the development of a technique for counting the numbers of insects, eelworms, etc., in the soil and the effect on certain of them of applications of substances such as carbon disulphide, chlordinitrobenzene, chlorpicrin, " seekay " and " cymag ". In 1936 the work was extended to cover tests of naphthalene and coal tar derivatives and the Agricultural Research Council approved a grant of £150 for the year from the 1st October, 1936, to supplement grants of £300 from Messrs. Imperial Chemicals, Ltd. and £300 from the Association of Tar Distillers.

Mr. Ladell has furnished the Insecticides and Fungicides Committee with a report on his work up to October, 1937. His first step was to devise a reliable technique for sampling a field soil to determine the number of insects present and the sampling error. For this purpose he has devised an ingenious apparatus which can separate the insects and other fauna from a 12 to 14 lb. sample of soil in 25 minutes. The soil is stirred up with a non-toxic solution of high specific gravity which frees the insects and flocculates the clay. Fine bubbles of air are passed up through the mixture of soil and liquid, separating the insects from the organic debris, most of which is held back by a sieve. The insects and a small quantity of debris are concentrated in a conical head and floated off the top of the liquid in the mixing tank, over the surface of a similar solution in a sedimentation tank on to a black filter paper in a Buchner funnel, where the liquid is filtered off under a pressure deficiency and the insects are retained on the paper. Very high figures of insect population have been obtained in this manner, up to 486 millions to the acre.

Using this technique the effect on wireworms of the substances mentioned above was determined in old grassland ploughed up for sugar beet, the fumigants being turned in at the time of ploughing and randomised plots of one-sixtieth of an acre, with controls, being used. In the first experiment " seekay ", chlorpicrin and " cymag " gave promising results in reducing the wireworm population and a further experiment on a new site with barley as the crop was carried out with " seekay " and a new chlorpicrin compound. " Seekay " reduced the wireworms by 61 per cent. and chlorpicrin by 33. The residual effects in the plots are being determined. The barley crop was poor on all the plots but was increased by the treatments.

In 1937 a number of small plots of old grassland ploughed up for winter wheat were treated in randomised blocks with various substances sometimes used as wireworm remedies, including lime, tar and lime, ammonium carbonate, superphosphate and naphthalene. The samples examined were necessarily rather few and the sampling error high, about 36 per cent., but the reduction of wireworms due to tar and lime, ammonium carbonate and naphthalene was significant; naphthalene appeared to be the most effective. Further experiments include two randomised field plot experiments in which, among other substances, monochlornaphthalene and orthodichlorbenzene in powdered form will be tested. Preliminary work has been done in specially devised types of pots and boxes to provide a satisfactory technique for pot experiments. Apparatus has also been devised to study the movements of wireworms in the soil and to see if they attempt to escape from toxic concentrations of the fumigant. Tests of baits for wireworms, with studies of their chemotropic response to various materials, have been carried out but have not so far given any clear indication of the best substance to use, as the attraction of those tested seems to be of restricted range.

Mr. Ladell has also carried out experiments on the effect of soil fumigants on eelworms in a field in which oats were severely injured by *Heterodera schachtii* and, to a lesser degree, by *Anguillulina dipsaci*. " Cymag " and carbon disulphide jelly, applied in March, both gave significant increases in yield and the latter inhibited the formation of new cysts of *H. schachtii,* no doubt by killing the larvae as they emerged from the cysts. A further experiment to test the effects on the cyst population in this field of clean weeding and of certain grasses, with and without chemical treatment, is in progress.

Imperial College of Science and Technology.

Mr. A. G. Pollard of the Agricultural Chemistry section of the Chemical Department under Professor J. C. Phillip has received aid from the Agricultural Research Council during the past two years for work on the more fundamental aspects of the problem of soil fumigation. The Council made grants to the College of £600 a year for two years from 1st October, 1935, to enable Mr. Pollard to employ two assistants, Dr. J. C. Higgins and Mr. T. G. Morris, to collaborate with him in these studies. The work during the period in question has been directed almost entirely to certain fundamental problems. The programme has included investigations of the physical and chemical properties of soil influencing the distribution and persistence of fumigant vapour in it, the measurement of these properties, and the application of the results to the pre-determination of the most effective dosage and method of applying fumigants to any particular soil. An examination of the distribution of fumigant vapour in soil in relation to the physical or chemical properties of the fumigant itself was a necessary part of this investigation and has been effected by direct core-sampling of the treated soil followed by chemical determination of the amount of fumigant present in the samples.

Carbon disulphide was selected for the early work largely because of its long use as a fumigant and consequent accumulation of biological data with which to compare the chemical results, but partly also because of its low solubility in water and the improbability of its rapid decomposition in the soil. Methods were developed for measuring the compactness of a soil, its pore space in uniformly compressed soils and the distribution of carbon disulphide in the soil after injection. After injection at 5 ins. the vapour shows a zone of high concentration around and below the level of injection, and loss of concentration is less downwards to about 12 ins. than towards the soil surface. Loss from the surface is rapid and there is no wide lateral movement of the vapour. The disulphide disappears from the soil rather quickly.

In field soils *in situ* the influence of moisture, temperature and compactness is very considerable. Effective concentrations of carbon disulphide could not be produced in the top 2 or 3 ins. by varying the level or amount of the injections nor by covering the surface with sacking, in a soil in which 90 per cent. of the test insects (wireworms) were killed at the lower depths. In this soil no concentrations of practical value were maintained for more than 40 hours and little for practical purposes after 24 hours, the injections being made 12 ins. apart and 10 grms. of CS_2 being used at 4·5 and 7.5 ins. for the two levels. In box experiments with uniformly prepared soil there was found to be, for each individual layer of the soil tested, a sharp rise after injection to a maximum concentration followed by a slower decline to a low concentration reached in about 24 hours at all depths.

The investigations in progress have been extended to include other fumigants possessing widely different physical properties. Shortly before the end of the period under review the Plants and Soils Committees of the Council appointed a small Committee to consider these investigations and those in progress under Mr. Ladell at Rothamsted, as it was thought that a stage might shortly be reached when some linkage of the two lines of approach to the difficult problem of soil fumigation might be effected. This Committee reported after the period covered by this review.

Long Ashton Experimental Station.

The Special grant made to the station for investigations of insecticides and fungicides from the funds at the disposal of the Agricultural Research Council amounted to £687 for the period from 1st July, 1934, to the 31st March, 1937. With this assistance a special fruit plantation was opened for testing, so as not to interfere with the other experimental plots at the station.

The work in progress at Long Ashton on insecticides and fungicides was seen by the Sub-Committee which visited the station and whose Report, referred to at greater length on p. 98, was adopted by the Council in November, 1936. The production of clean fruit requires strict adherence to a lengthy and complicated spray programme, but research has now shown that a shortening and simplification of this programme is made possible by modification of the spraying appliances and by the use of combined washes (see p. 144). Dr. T. Swarbrick has published an account of the economies in time and cost effected by different apparatus for spraying, with special reference to mobile power sprayers.

To accelerate progress in the development of effective combined washes the problem has been analysed to phases amenable to laboratory investigation. Thus, the physico-chemical factors determining the retention of spray fluids to plant surfaces have been examined by Dr. H. Martin and his collaborators, especially in regard to the effect of adding wetters and spreaders upon the retention and tenacity of the spray deposit. The examination of more complex sprays containing emulsions has been completed, thus covering the entire range of liquid/solid systems employable as sprays. The subject has been treated from the fundamental aspect of the mechanics of spray deposition but conclusions susceptible of practical application have been, or will be, subjected to field trial as opportunity arises.

Laboratory methods have been devised for the biological examination of combined washes. In the tests of fungicidal properties Mr. R. W. Marsh has taken a prominent part and in those of ovicides and winter washes, Dr. H. G. H. Kearns, but the biological aspects of the investigations have been carried out in close collaboration with Dr. Martin and his staff on the chemical and physical sides; Dr. Swarbrick has taken a prominent part in the field tests. The visiting Sub-Committee noted with appreciation the real team spirit inspiring this work at Long Ashton and made a strong recommendation that should the grant from a commercial firm which enabled Dr. Martin to employ additional chemical assistance lapse, immediate steps should be taken to maintain this assistance. They also recommended the appointment of an additional chemical technical assistant.

The detailed studies of the copper fungicides which have been in progress for some years showed that a wide range of copper compounds had fungicidal powers. Recently they have been extended to the copper oxides in collaboration with an American research worker, Dr. J. G. Horsfall. It was found that, while the method of manufacture and the particle size influenced fungicidal value, cuprous oxide inhibits spore germination in the laboratory better than cupric oxide. Preparations containing cuprous oxide as the active fungicide are less troublesome to prepare and apply than Bordeaux mixture and are available commercially. Laboratory tests have also shown the ovicidal value of certain organic thiocyanates and one, dodecyl (lauryl) rhodanate, has been suggested as a substitute for tar oils in winter washes. Investigations of the physico-chemical properties which determine the ovicidal action of tar and petroleum oils have been completed and it now seems possible, by analytical methods, to make an estimate of the field performance of products compounded from these materials. An important objective in work of this nature is the standardisation of products available to the grower for the control of pests.

East Malling Research Station.

The special grants made from the funds at the Council's disposal for the development of work on insecticides and fungicides at this station amounted to £2,445 in all between the 1st July, 1934, and the 31st March, 1937. They provided for the addition of a chemist, Dr. H. Shaw, to the staff and when the station was visited by the Sub-Committee whose Report is more fully referred to on p. 98, two mycologists, Mr. M. H. Moore and Mr. H. B. S. Montgomery, and an entomologist, Mr. W. Steer, were also engaged on these investigations, contributions towards the total cost of which were also received from a commercial firm.

The laboratory investigations have included studies of the ovicidal properties of different fractions of tar distillates obtained in part from the Fuel Research Station and extending to high temperature carbonisation products of horizontal and vertical types of retort and fractions of a hydrogenated tar distillate. They have been tested on the eggs of the vapourer moth, winter moth and *Aphis pomi*. Investigations have also been carried out on other substances present in the distillates, including various heterocyclic bases, some of which proved to be toxic, several of the less complex hydrocarbons, and a sulphur derivative. Comparative tests were made with petroleum oils. A number of organic chemical substances, mostly synthetic and including nitrophenols and some alkaloids which merit extended testing, have also been examined as ovicides.

As contact insecticides a range of chemical substances have been tested including organic thiocyanates, thiophenols and derivatives, anabasine and thiodiphenylamine. The more toxic thiocyanates caused injury to the trees at effective concentrations. Thiodiphenylamine requires fuller investigation as a contact poison and was outstanding as a stomach poison in the laboratory though less effective in small-scale field trials.

Throughout this work the relation of chemical constitution to insecticidal action has been of major interest to Dr. Shaw; the elaboration of analytical methods has been a necessary preliminary step.

In the laboratory testing of protective fungicides a special technique has been devised and used for the evaluation of a number of new chemical preparations. Some of these are promising, especially tetramethylthiuram disulphide. Field trials have partially confirmed the promise of this substance, a

25 per cent. dispersion of which caused no injury to the sprayed trees at concentrations up to 1 per cent. Special attention has been given to the differences in fungicidal activity arising from changes in molecular structure.

Field trials of a number of substances, proprietary and other, have been carried out especially with a view to determining their phytocidal properties as evinced by leaf and fruit injury. In many of the tests Cox's Orange Pippin apples, readily injured by certain substances such as copper compounds, were used. The addition of ferrous sulphate protected the trees from defoliation by lime sulphur applied at 1 in 60 as a post-blossom spray, but did not prevent fruit drop. Field tests of combined fungicide-insecticide sprays are also in progress. A comprehensive investigation of the persistence of arsenical residues on apple fruit has been carried out and has proved that an application of lead arsenate in late June, which has been shown at the station to be effective in reducing damage from codling moth, is unobjectionable. Cheap mineral oils are being tested to determine if they can replace the more expensive summer-grade oils at present in use. A cheap mineral oil was effective in winter spraying against red spider.

The Experimental and Research Station, Cheshunt.

The studies on insecticides and fungicides at this station carried out by Mr. W. Read deal mainly with the control of diseases and pests injurious to glasshouse crops. Tests have been carried out with various substances, including acetic acid and hydrogen peroxide, as substitutes for formaldehyde in soil disinfection. They were tested against *Phytophthora cryptogea,* the fungus mainly responsible locally for damping off of seedlings. Acetic acid failed to give control at 1 per cent. concentration and hydrogen peroxide at 0·75 per cent. None of the others was effective at amounts harmless to the seedlings. Laboratory tests of various petroleum oil emulsions which had proved unsatisfactory for the control of the red spider mite (*Tetranychus telarius*) in cucumber nurseries, showed that failure to kill the mite was due to the formation of over-stable emulsions which failed to break on contact with the mite or leaf surface. Injury to the plants resulted from the use of unsuitable oils and emulsifiers. Certain organic thiocyanates were effective in killing the mites but not their eggs.

An attempt has been made to find substitutes for the basic copper chloride suspension used in combination with petroleum oil emulsions for the joint control of red spider mite and fungus diseases such as tomato leaf mould (*Cladosporium fulvum*), cucumber mildew (*Erysiphe cichoracearum*) and rose mildew (*Sphaerotheca pannosa*). Promising results have been obtained with several insoluble copper compounds.

South Eastern Agricultural College, Wye.

At the South-Eastern Agricultural College, Wye, Mr. C. Davies has continued his investigations of the mechanics of spraying, for the prosecution of which he has devised special methods of determining the output and range of spray nozzles at different pressures. He has introduced new types of spray guns in which the control of the spray is effected by the mere raising or lowering of the rod. He has also done much work on nozzles with a view to improving the symmetry and evenness of the spray deposit, the degree of atomisation produced and the range and output of the liquid.

Insect physiology in relation to insecticidal action.

As mentioned in the Council's last report, proposals for work on the physiological aspects of the action of toxic substances on insects were received from Professor J. W. Munro of the Imperial College of Science and Technology in 1935. A grant was made by the Council to the College of £900 for the academic year 1935-6 and a further grant of £650 for the following year. Under these grants Dr. G. Fraenkel has been engaged for the work and laboratory equipment has been provided.

The investigations involved a detailed study of the physico-chemical and physiological properties of the insect cuticle, especially in regard to its permeability. The ingress of oxygen through the cuticle has been demonstrated in the blowfly, *Calliphora erythrocephala,* in which it has been possible to keep the larvae alive after eliminating the penetration of gases or liquids through the spiracles and tracheae. This technique has been used to test the permeability of the cuticle after treatment by various solvents. With Professor Munro and Dr. Potter, Dr. Fraenkel has also begun a study of the specific action of pyrethrum as an insecticide, in order to determine the system or systems affected. The relationship between the toxicity of an insect poison and the rate of metabolism of the insect is also under study. The nutrition of the adult blowfly has been investigated and work on the carbohydrates completed. An investigation of the physiological action of high temperatures on insects is also in progress. Research students under Dr.

Fraenkel's supervision are engaged in investigations on nutrition in various insects, on the diapause or dormancy in *Lucilia* and *Ephestia* and other physiological problems.

The Insecticides and Fungicides Committee have expressed the hope that it may be possible to place this work on insect physiology, which is fundamental to many of the investigations in which they are interested, on a more permanent basis.

The standardisation of methods of testing the efficacy of Insecticides and Fungicides.

This question was discussed by the British Commonwealth Scientific Conference held in London in 1936, and a report on the aims and progress of research having this end in view, carried out in Great Britain under the co-ordination of the Committee on Insecticides and Fungicides, was furnished to the Conference. The Conference resolved to direct the attention of National Research Councils and similar bodies in the Commonwealth to the need for fundamental research into methods for the biological standardisation of fungicides and insecticides and suggested that intercommunication between the workers engaged in such studies might be facilitated if each country set up a suitable organisation to consider their co-ordination.

ENTOMOLOGY.

Entomological research is in progress at most of the research stations dealing with plant problems, while the field control of insect pests is mainly in the hands of the corps of advisers in entomology attached to the various provinces of the Advisory Officers' Scheme. The Plant Pathological Laboratory of the Ministry of Agriculture and Fisheries at Harpenden deals generally with scientific and technical questions relating to the pests and diseases of plants, including (*a*) matters arising out of the administration of the Destructive Insects and Pests Acts, 1877 to 1927, and of regulations governing the import, export, or sale of plants; (*b*) the preparation of periodical reports on the incidence of diseases and pests, of leaflets, and other publications; (*c*) the identification of pests and diseases and the provision of technical advice by means of correspondence and visits; (*d*) the inception and co-ordination of research and advisory work in entomology and phytopathology at research institutes and colleges; (*e*) questions relating to insecticides and fungicides, their composition, standardisation and use. During the period under review the Director of the Laboratory, Mr. J. C. F. Fryer, supervised a most successful campaign to prevent the spread of the Colorado Beetle beyond the limited area of the Thames Estuary orginally affected and to eradicate the pest from this area. Research on insects affecting stock is referred to in the Chapter on Animal Diseases (see p. 258).

Rothamsted Experimental Station.

The Council received a report on the entomological work at Rothamsted, based on a visiting Sub-Committee's observations, as part of a general report on the station presented in April, 1936. The entomological department was established in 1918-9 to form, jointly with the mycological department established at the same time, an Institute of Plant Pathology, administratively distinct from the Experimental Station and receiving separate maintenance grants from Government. The Institute became merged with the station about 1922 and the original intention of founding a national phytopathological centre was abandoned with the absorption of its two component parts into departments of the station.

The work in progress is largely long-range and wide-range research of the kind with which Rothamsted has always been identified. Dr. C. B. Williams, the head of the department, is engaged in a study of the broad problems of the fluctuations of insect numbers in relation to climate, weather and diurnal conditions, and of insect migration. Other members of the staff are carrying out intensive studies of particular groups or species of insects such as those of Dr. H. F. Barnes on the gall midges (in which population studies are also included), the asparagus miner (*Melanagromyza simplex*), the hollyhock seed moth (*Platyedra malvella*) and the common crane fly (*Tipula paludosa*); the physiological relationship between insects and their food plants; the parasites of insects; and the numbers of insects in the soil.

The Council considered that an attempt to divorce fundamental from applied work in this department as well as in that of plant pathology would be unwise and frequently impossible, but that the method of treatment of the subject studied could with advantage often be such as to keep in evidence its relation to agriculture; there might be reason for watchfulness to prevent investigations from diverging into channels of purely academic interest. Certain recommendations for an increase in laboratory assistance and in the grant for maintenance were also made.

The bee investigations form part of the activities of the department but with a separate staff and finance. They will be mentioned in subsequent pages (see p. 154).

Long Ashton Research Station.

For some years after the foundation of the station a general plant pathologist was responsible for work on entomology. In 1922 the first appointment of a whole time entomologist was made. Frequent changes of staff since then up to a comparatively recent period caused a certain lack of continuity in the research work, but research into winter washes, especially of the tar distillate type, has formed a prominent feature of the work for many years. When the station was visited by a Sub-Committee of the Plants and Soils Committees, whose report was adopted by the Council in November, 1936, the research entomologist, Dr. H. G. H. Kearns, was collaborating with the group of workers engaged with Dr. Martin in the investigation of insecticides (p. 138) and with Dr. Swarbrick in studies of spraying technique in the plantations. He had also dealt successfully with methods of controlling the apple sawfly and various pests of basket willows and was engaged in work on the plum sawfly with promising results. In collaboration with Mr. Marsh, the research mycologist at the station, considerable advances have been made during the past few years in the use of combined washes for the joint control of insect pests and fungus diseases of fruits. The timing of the spraying has been found to vary according to locality, altitude and season, even within the limits of the Bristol Province; thus, the spray date for apple sawfly in Somerset is usually a week later than in Worcestershire and for apples grown at 500 ft. above sea level usually a week later than for those nearby at 150 ft. to 200 ft. A spray programme service has been established by the station in co-operation with the county agricultural staffs, and useful summaries of the requisite materials and methods for controlling the major pests of different fruits have been published. Leaflets and Press notices are issued immediately prior to the correct spraying date. The special requirements of pest control in nursery fruit stock have been studied by Dr. Kearns, who has emphasised the necessity for anticipating insect attacks in nurseries if injury to the framework of the tree or bush is to be avoided. Programmes of routine preventive treatments of various kinds of fruit nursery stocks have been worked out.

Dr. Kearns has, in addition, been much concerned with investigations of problems arising from the station's advisory work, involving in most cases a study of the bionomics of some insect and control experiments based on the knowledge obtained. Work on the codling moth and the raspberry moth are cases in point. Investigations of this type arise primarily from the appeals of the grower for help, but the work involved is not necessarily simple or restricted in scope. The Sub-Committee thought that these appeals for assistance of an advisory nature, which were increasing, might become a severe tax on the research activities of the entomologist. The fact that Dr. Walton, the Advisory Entomologist for the Bristol Province, is also stationed at Long Ashton does not eliminate this danger, for the advisers at Long Ashton are concerned with all crops and not only with fruit. It was suggested that if this trend continued to require more and more of the time of the station's entomologist it would seem that the existing (geographical) distribution of the Advisory Entomologists might need reconsideration.

East Malling Research Station.

The first entomologist appointed to the staff for whole time work in 1923 was Dr. A. M. Massee, who still remains in charge of the entomological section of the station. He is assisted by Mr. R. M. Greenslade, while Mr. W. Steer is the entomological member of the team engaged in insecticidal and fungicidal investigations.

The principal long-range investigation in progress at the time of the visit of the Sub-Committee which reported to the Council on the work of the station in November, 1936, was that on the resistance of apples to woolly aphis attack. This work has already been mentioned in the account of the plant breeding work of the station on p. 107 of this Report. Other investigations included studies on certain Eriophyid mites, a group on which Dr. Massee is a recognised authority. Very considerable work has been done on the strawberry Tarsonemus, a mite which is one of the causes of strawberry failures, and work on the black currant mite, the suspected carrier of the "reversion" virus disease of black currants, and other possible vectors of this disease was also being taken up. Detailed experiments with bands treated with various poisons against the apple blossom weevil were also in progress. Dr. Massee was collaborating with Mr. Harris in a study of aphids as vectors of the strawberry virus disease known as yellow edge. Experiments in the control of the raspberry beetle by the use of derris sprays were carried out by Mr. Steer during 1932-4 with the aid of a grant from the Agricultural Research Council, who received a final report on it in January, 1936. The results were regarded as very satisfactory.

As at Long Ashton, much of the work of this section has developed from appeals for aid from the growers. This has led to increasing pressure on the time available for research and the Sub-Committee were of opinion that the interests of horticulture might be better served if Dr. Massee could be relieved of some of this pressure. They took note of the fact that the security of tenure of appointment of the junior entomologists of the staff was uncertain and recommended that there should be not less than two entomological posts on the permanent establishment and thought that a third (not necessarily graded) might well be required to carry out the programme in hand.

Horticultural Research Station, Cambridge.

When the Horticultural Research Station at Cambridge was visited by a Sub-Committee which reported to the Council in November, 1936, entomological work was temporarily in abeyance owing to the resignation of the entomologist at the station shortly before the time of the visit. Mr. D. H. Wright became entomologist in June, 1936. The Sub-Committee were impressed by the need for entomological work at the station and held that it would be most fruitful if concentrated more on problems arising from the breeding work (e.g., varietal susceptibility to attack by pests) and on the practical problems brought to light by close contact with vegetable growers. These latter could only be appreciated by personal observations in the growers' fields; those selected could then be more intensively studied at the station. This would entail some additional provision on the grant to encourage touring; an increase for the purpose has since been approved.

Mr. Wright has commenced a detailed study of the life-history of the cabbage aphis (*Brevicoryne brassicae*) in co-operation with Mr. F. R. Petherbridge, the Advisory Officer in Entomology. A study is also being made of differences in susceptibility of varieties of Brassicae to this insect pest and an investigation of the meteorological factors governing the migration of the winged form of it. Other work in hand includes experiments in the control of the onion fly (*Hylemyia antiqua*) and the cabbage root fly (*H. brassicae*).

The Experimental and Research Station, Cheshunt.

Pest control is an important feature of the work on glasshouse crops at the Experimental and Research Station, Cheshunt. Mr. E. R. Speyer, the entomologist of the station, has carried out detailed studies of the bionomics of the species of thrips that attack, amongst other plants, the carnation and the rose under glass, and many experiments on their control have been made. The former (*Thrips tabaci*) breeds in the flower and is probably disseminated by means of returnable flower boxes. Naphthalene fumigation has been effective in ridding houses of it. The rose thrips (*T. fuscipennis*) breeds on young foliage and flowers and can be poisoned by a brown sugar bait containing sodium fluoride, but no practicable method of control has yet been found. The greenhouse white fly (*Trialeurodes vaporariorum*) was formerly a serious pest in the Lea Valley but has been so heavily reduced by the parasitism on it of another insect, *Encarsia formosa,* investigated by Mr. Speyer, that it is no longer feared. The breeding and distribution to growers of this parasite is part of the routine work of the station. Work on the control of the red spider mite, *Tetranychus telarius,* by derris insecticides has also been undertaken, together with a study by Mr. W. H. Read of the temperature required to combat this pest by naphthalene fumigation on carnations, which it was found could be effectively fumigated at external house temperatures above 40° F. without injury to the plant, in the absence of soft young growth. On cucumbers red spider can be controlled by petroleum oil emulsions with a naphthalene fumigation in late severe attacks.

The Welsh Plant Breeding Station, Aberystwyth.

With the co-operation of the zoology department of the University College of Wales and of Mr. J. R. W. Jenkins, the Adviser in Agricultural Zoology, studies have been carried out at the Welsh Plant Breeding Station on several pests of grasses. The distribution and intensity of midge attack on the inflorescences of grasses grown for seed production have been investigated. The most destructive midge proved to be *Contarinia merceri,* which causes a very serious reduction in the yield of viable meadow foxtail seed. Control measures are based on growth at high altitudes and cutting back in the spring so as to delay seeding. The latter measure, however, was found to cause too great a loss of yield to be generally practicable. Clover weevils (*Apion* spp.) also cause serious losses to the seed production of red clover, but their numbers may be reduced by mowing field clover in the neighbourhood of the seed crop before the full flowering stage is reached. The eggs which are laid in the early flowering stage are killed by the drying out of the heads, and if this early cutting is regularly practised the seed crop may be largely safeguarded.

The Universities and Agricultural Colleges.

The advisory officers attached to universities and agricultural colleges in England and Wales and in Scotland are mainly concerned with the field control of pests. In a number of cases, however, their work involves studies of life-histories, bionomics, ecology and systematics, and in some, anatomical or morphological studies have also been undertaken. The ecological work on the aphid vectors of potato virus diseases at the University College of North Wales has been referred to above (p. 129). At Seale Hayne Agricultural College very extensive investigations have been carried out by Mr. L. N. Staniland, Advisory Entomologist, on the heat resistance of various plant eelworms, especially those injurious to bulbs and to violets, as an aid to the control of these pests by the hot water treatment. In the development of a technique for measurement of the temperature of bulbs in any part of the bath Mr. Staniland has had the advantage of the co-operation of Mr. D. R. Barber of the Department of Physics, University College, Exeter. This work was seen by the Sub-Committee which visited Seale Hayne in 1936 to report on the broccoli breeding experiments of Mr. Horne (see p. 81). It has shown that the methods in current use are unreliable, and enabled standardised instructions regarding the size, design and loading of the bath, the adjustment of the thermometer and the duration of treatment, to be drawn up. A type of bath specially adapted for the hot water treatment of strawberry and violet runners has also been devised. In the strawberry the treatment is specially required for use against Tarsonemid mites.

At Manchester University Dr. H. W. Miles, the Advisory Entomologist, started work in 1925 on the control of wireworms but was unable to pursue it for long owing to pressure of other work. This pest has become unusually destructive of recent years, especially in Cheshire, and an application was made to the Agricultural Research Council early in 1937 for financial support for a co-operative scheme of investigation to be conducted at the University under Dr. Miles's direction. Other bodies contributing to the investigation were the Potato Marketing Board, the Sugar Beet Society and the National Farmers' Union (Cheshire Branch). It was proposed to appoint a special investigator and provide him with a field laboratory, apparatus and a maintenance grant. The Council gave general approval to the scheme at their meeting on 21st April, 1937, and authorised a grant not exceeding £75 for initial apparatus and fittings and £227 10s. for running expenses for the six months to 30th September, 1937. Dr. Morris Cohen was appointed assistant to Dr. Miles for this investigation. Financial provision has been made for the continuation of the work for the academic year 1937-8 at an estimated cost of £655, of which the Council have agreed to provide £470. It is estimated that the programme will require five years to carry out; it is concentrated mainly on the field and cultivation aspects of control, and covers a study of the life histories of the several species injurious to crops in Cheshire, the soil conditions and cultural operations affecting their activity, the effect of rotation and trap cropping upon their numbers, and the influence on them of artificial manures and soil insecticides.

At Reading University field investigations of the pests affecting strawberries have been carried on by Mr. W. E. H. Hodson, Advisory Entomologist, for several years. Early in 1937 the University applied for a special research grant from the funds at the disposal of the Council in order to expand this work by the appointment of a scientific assistant and to provide for a combined attack on the problem of the deterioration of strawberry plantations in Hampshire by entomological, soil, drainage and manurial investigations. The work would mainly be done at the Hampshire County Council's Fruit Station at Botley and would be supervised by Mr. Hodson and Dr. F. F. Kay, the Soil Surveyor for the Reading Province under the Advisory Officers' Scheme, with advice on the soil experiments from Dr. T. Wallace of Long Ashton and on drainage from Professor R. Rae, Professor of Agriculture in the University. Grant aid was asked for at the rate of £505 for the nine months from 1st June, 1937, to 30th March, 1938, and £536 for the financial year 1938-9, with some assurance of support for a third year since the Hampshire County Council had offered, if a three-year programme were accepted, to provide a field laboratory at Botley at a cost of £140. The Council approved a grant of £505 for one year conditional on the provision of not less than £140 from the County Council for the field laboratory, but stipulated that the work should be reviewed in the early spring of 1938 before the grant could be renewed.

There is much difference of opinion as to the cause of deterioration in strawberries which, though specially serious in the important strawberry plantations in Hampshire, is by no means confined to that area. It is proposed to attempt to separate out by field experiments at and near Botley such soil factors as may be implicated, from the pest and disease injury that appears undoubtedly to play a part. This it is proposed to do by the establishment of plots kept free from pests and diseases. At the same time work on strawberry pest control, including where necessary further studies on the pests themselves, will be intensified.

In Scotland entomologists are attached to the Edinburgh and East of Scotland Agricultural College in Edinburgh and to the North of Scotland Agricultural College at Aberdeen. None is employed at any of the research institutes and those attached to the Edinburgh College only give part of their time to agricultural work as they hold other university appointments. At Edinburgh Dr. A. E. Cameron has two assistants, one of whom works generally on agricultural pests. The work on slugs attacking the potato crop has been referred to above (p. 117). Other work in progress includes an investigation of cabbage root flies and the swede midge. In Aberdeen Dr. Guy Morrison is employed whole time at the College and has engaged in the study of the aphides on potatoes as having a bearing on the spread of virus diseases in this crop, on the control of cabbage root fly and turnip flea beetle (*Phyllotreta undulata*) and on tests of various insecticides. Severe attacks of the turnip root fly, *Phorbia floralis*, occurred in 1936 and led to a study of this pest. It was found attacking all varieties of swedes and turnips, leading to the subsequent development of storage rots which may entirely destroy the turnips. Its life history has been followed out but no satisfactory method of control on a field scale has as yet been found. This work is still in progress in collaboration with the Macaulay Soil Research Institute.

Both these Colleges have been concerned in the study of the heather beetle (*Lochmaea suturalis*), a pest which is of economic importance chiefly because of the injury to grouse moors which it causes. The Agricultural Research Council were unable to accede to an application for financial aid towards a more intensive investigation of this pest in 1936, owing to its relatively minor importance in agriculture, but support was forthcoming from the British Field Sports Society which has permitted of the employment of a special assistant for this work, attached to the staff of Dr. A. E. Cameron.

Breeding of Oat varieties resistant to Frit Fly.

On this problem Dr. N. Cunliffe is engaged at the School of Rural Economy, Oxford. The work is financed by a grant-in-aid from the Development Fund made on the advice of the Agricultural Research Council.

The investigation has proved to be an exceedingly laborious one but it has now reached the stage when certain of the resistant oat strains are undergoing field tests for suitability for distribution.

Attacks of the frit fly were severe at Oxford in 1934 and 1935 so that the resistant selections were exposed to a rigorous test and the differences in behaviour of the strains were accentuated. The sowings are normally arranged so that the plants are exposed to the maximum seasonal attack while still not beyond the fourth leaf stage; resistance to the first brood of the fly grows after this stage, and the second brood's attack at flowering time is less serious as it does not prevent the grain from forming but only makes it light. The selections are submitted to statistically controlled analyses for loss of primary shoots due to attack, yield, tillering and so on.

Much of the work has been done on crosses between the two resistant Swedish varieties, Spet and Summer, and commercially valuable varieties such as Abundance, Victory, Star, King and the like. From the Spet-Star crosses a series of allied strains of promise were early obtained and single plant isolations from these have been continued. Studies on one of these strains, No. 303173, have shown that it possesses distinct inherited resistance against frit fly but is not yet genetically pure in regard to resistance for there are strains within it, some as resistant as the Spet parent and others less so. It has been tested fully on the plot scale against Victory both at Oxford and Cambridge and found to yield as well even excluding its capacity to withstand injury from frit fly, to have no higher a percentage of husk to grain, to be earlier, and to have a greater weight per 1,000 grains, than Victory. Its straw is average as regards yield but possesses a high degree of " resilience ". It has more panicles than Victory but only about three-quarters as many spikelets. Another allied Spet-Star cross, No. 303176, has similar characters but a higher percentage of husk to grain than Victory.

In a series of crosses between the resistant Summer and the susceptible Star and Victory varieties, now in the F9 generation, some promising strains in regard to resistance, number of spikelets, weight of grain and percentage of husk, have been obtained. Some of the Summer-Star crosses have a resistance equal to that of No. 303173 but still less than that of the Summer parent. They also seem to have more spikelets than the Spet-Star crosses. Single plant isolations of this series are still in progress.

In 1935 significant differences in the carbon:nitrogen ratio were observed between one of the resistant Spet-Star selections and Victory. Preliminary analyses showed that the resistant strain had 26 per cent. more carbohydrate per unit weight of nitrogen in its primary shoots at the 5 to 6 leaf stage and 20 per cent. more in its tillers than Victory. An application made for an increase in the grant for the year 1936-7 to provide chemical assistance in following up these indications was supported by the Agricultural Research Council. This assistance was provided; meanwhile further work showed that the resistant strain had 28 per cent. more dry matter, over 6 per cent. more total carbohydrate, over 5 per cent. more soluble carbohydrate, and nearly 10 per cent. more crude fibre in its primary shoots than Victory. These results suggest the possibility that resistance may be due to some quality in the skeleton of the plant that makes it more difficult for the larvae to penetrate, whether greater thickness of cell wall, smaller cells or more fibres. There was some evidence of a difference also in the silica content, but the differences were scarcely significant.

It is hoped that this work will provide a quicker and more certain criterion of resistance than the method of exposure to attack in the field that has hitherto been necessary. Work on the effect of date of sowing and the influence of environmental conditions, such as temperature, on the intensity of attack is also in progress, as well as further selections from the existing material and from crosses with new resistant selections from Sweden, including further strains of Spet from Svalöv.

The work hitherto accomplished has established that resistance to this serious oat pest is an inherited quality, fluctuating according to the weather variations of the season but maintaining its relative constancy when compared with the fluctuations found in the commonly grown susceptible varieties. This character can be combined by hybridisation and selection with the high qualities of the good susceptible varieties. A still higher degree of resistance combined with quality and yield may be obtained in future. The present series of field trials arranged by the National Institute of Agricultural Botany will show how far the new strains are suitable for extended cultivation.

Biological Control of Insect Pests.

As mentioned in the last Report, the Agricultural Research Council made a grant in 1935 to enable work on the fundamental problems involved in the use of parasites as a means of controlling insect pests to be carried out at the Farnham House Laboratory of the Imperial Institute of Entomology. This grant was renewed for six months from 1st August, 1936, to give time for the consideration by the Commonwealth Scientific Conference of the future of this work on a basis of Imperial financial co-operation. Mr. G. C. Ullyett, to whom the work was entrusted, obtained an appointment overseas before the completion of the grant period, and the Conference did not recommend Imperial co-operation for the support of fundamental investigations of this nature. The work is, therefore, in abeyance for the time being.

Mr. Ullyett submitted a report to the Council on the first year's work in the autumn of 1936. He set out to find a laboratory method of measuring the efficiency of a parasite or predator in keeping down the numbers of the insect it attacks. The parasite selected for the investigation was the Chalcid insect, *Microplectron fuscipennis,* which attacks the resting-stage larvae of the sawflies that injure pine and spruce trees. The study involved at every step the relations of the two insects. As a preliminary the optimum conditions for parasitic activity, the range of climatic conditions under which the parasite can increase sufficiently to control its host and the effect of these conditions upon the general interaction of the two were studied.

Microplectron was found to be able to pick out its true from false hosts and to discriminate between sawfly larvae that had already been attacked and healthy ones, provided the parasite had developed beyond the egg stage in the larva.

Some parasites do not thrive unless their hosts are densely distributed; they, therefore, do not prevent the attacked insect from multiplying to a serious extent and they cause violent fluctuations by rapidly reducing concentrated populations. Others thrive at low host densities and can keep the injurious insect always under a measure of control. Investigations on *Microplectron* showed that it belongs to the latter class. It searches out its hosts, and the range of its search is greater according as the numbers of sawfly larvae in a given area are less. It searches at random and its success, which is directly proportional to the number of host insects per unit area, is capable of mathematical calculation. By a simple experiment it is possible to gauge the value of such a parasite at various densities of population of its host and to say whether it is likely to be worth introducing as a means of controlling a particular pest. The work also gives important information on the advantage to be expected from heavy introductions of the parasite; doubling the numbers of the latter does not double its efficiency. This follows from the random nature of the search and the resulting overlapping of the units of area covered by one parasite during its search with those covered by other parasites of the same batch. In actual fact a point is reached above which any further addition to the number of parasites released is economically unsound. These results break new ground in the study of this subject and mark an important advance in knowledge of the principles underlying the use of parasites in pest control.

Bee Research at Rothamsted.

Investigations on bees are carried out mainly in the Entomological Department at Rothamsted, where Mr. D. M. T. Morland has been in charge of them for the past 15 years. They cover studies of the bee in health and have recently included studies of some of the diseases of bees, and on honey production and honey quality. They have aroused considerable interest among bee keepers and receive financial support from Bee Keepers' Associations and individuals.

In 1934 Dr. H. L. A. Tarr was appointed to carry out intensive work on the brood diseases of bees under a special research grant from the Agricultural Research Council. This grant was renewed for the year from 1st October, 1935, at the rate of £250, the bee industry providing an additional £250. It was again renewed for the following year, the Council providing £300 and the bee keepers £250; further provision has been made for its continuation in the current academic year. Dr. Tarr has already made important advances in knowledge of these diseases. He has shown that European and American Foul Brood are two distinct diseases, confirmed that the latter (the American form) is due to a bacterium, *Bacillus larvae,* and is a true infective disease occurring even in strong well-nourished colonies;

the European disease is also highly infectious and though it tends to be most pronounced in weak stocks, these have often become weak from recurrent attacks on originally strong colonies. Strong stocks have been found not infrequently to be seriously attacked. In Dr. Tarr's view it is a specific disease caused by *Bacillus pluton,* but other secondary organisms are associated and confuse the symptoms. *B. pluton* is regarded as a strict parasite which appears to multiply only in the young normal larvae and has not been cultivated outside the body. It is possible that it sometimes requires the presence of one or other of the associated organisms before it becomes actively parasitic. A third brood disease, known as Addled Brood, was found to be prevalent in Great Britain. Approximately one-third of the brood diseases sent in were due to this trouble. It is not directly an infectious disease being due to some defect in the queen, but whether this is an hereditary disability or caused by some diseased condition in the queen is not known; this question is now being studied. The disorder can be obviated by removing the queen and introducing a new sound one.

Further work on *Bacillus larvae* showed that the conditions under which this organism can set up an attack of American Foul Brood are not simple; it is possible that the bee itself plays some part hitherto unknown in the causation of the disease and work is in progress to elucidate this point.

Dr. Tarr's investigations have now reached a stage when the improvement of the control measures taken against brood diseases has become their immediate aim; there is still much to be done before control can be perfected on rational lines.

In 1936 application was made for a special research grant from the funds at the Council's disposal in order to undertake an investigation on honey quality. For this purpose a grant not exceeding £520, to include the cost of some special apparatus, was made for the year from 1st October, 1936, and provision has been made for its continuance during the current year. Dr. C. R. Marshall was appointed to undertake the investigations. He commenced a study of the physical properties, and a survey of the methods of chemical analysis, of honey. For exact work it has been found necessary to estimate directly both the glucose and fructose. The ratio of fructose to glucose affects the physical properties of the honey, particularly those concerned in its storage—degree to which it will absorb or lose moisture and the like. Under our climatic conditions the honey is generally in a condition to take up moisture and it should be kept in a dry place or in air tight containers. Attention is being particularly paid to the bearing of the moisture relationship, on fermentation in honey and the limiting value of osmotic pressure above which fermentation will not occur. Studies on viscosity as affected by temperature, composition and the like have been commenced. The special property popularly assigned to heather honey of being able to hold more water than other honeys without fermenting is associated with the viscosity relations of these honeys.

Mr. Morland's main work is on the methods of swarm control and on the feeding of bees. There is an experimental apiary on the farm, in which a large number of colonies are maintained, besides out-apiaries for special investigations and work on diseases. The hives can be weighed by continuous self-recording balances. Experiments are carried out with bees marked on emerging from the cell and introduced into observation or other hives. Some support has been obtained for the " brood food " theory of Gerstung, according to which swarming results from the building of queen cells when there is a surplus of nurse bees over the requirements of the brood. The extent and period of this surplus depends on a number of factors. In conjunction with the Physics Department he has also undertaken a study of viscosity and the increase in viscosity which occurs in certain honeys (including those from ling heather) on standing undisturbed, while when stirred their viscosity decreases (thixotropy).

Bee conferences are held periodically at Rothamsted and are very largely attended, while both Mr. Morland and Dr. Tarr are much consulted by keepers and the Bee Associations.

Mycology and Bacteriology.

Much active research is in progress in the research institutes, universities and colleges on the diseases of crops caused by bacteria and fungi. As in entomology, the more practical side dealing with the field control of the diseases is largely the duty of the advisory mycologists appointed to each of the advisory provinces in England and Wales. In Scotland the advisers in Plant Husbandry attached to the Glasgow and West of Scotland Agricultural College have concerned themselves largely with investigations of plant diseases. The advisory bacteriologist at the Edinburgh and East of Scotland College gives some time to bacterial affections of plants, and those due to fungi are dealt with by the botanical and other members of the staff.

Rothamsted Experimental Station.

The plant pathological work at Rothamsted is under the charge of Dr. J. Henderson Smith who is himself an active worker on virus diseases and leader of the team engaged in studies of plant viruses at the station; an account of this work has been given in the section on Virus Diseases (p. 122). The chief work on fungous diseases of crops is that on take all (*Ophiobolus graminis*) formerly carried out by Mr. G. Samuel and now by Dr. S. D. Garrett, and on finger-and-toe (*Plasmodiophora brassicae*) by Mr. Samuel.

At the time of the visit of the Sub-Committee whose report was adopted by the Council in April, 1936, Mr. Samuel had only recently taken up his duties at the station and the additional glasshouse accommodation required for the extension of the pathological work to deal more specifically with crop diseases had not been provided. In 1936 it was decided to develop the work more on field problems and especially, in view of the unique body of information on soil conditions available at Rothamsted, on those diseases whose incidence is associated with soil factors, of which the two mentioned are good examples. This was in line with the Sub-Committee's recommendation that the long-range and wide-range investigations with which Rothamsted has always been identified should be directed, in the departments dealing with pests and diseases of plants, so as to keep in evidence their relation to agriculture. In point of fact there are probably few more pressing problems than the safeguarding of the wheat crop from the diseases likely to become intensified under the present extension of wheat growing on to the lighter soils, its more frequent repetition in the rotation especially on mechanised farms, and the change in farming practice due to a reduction in the feeding of stock with roots and the replacement of the latter with a pasture grass seeds mixture, which is liable to certain root diseases similar to those that attack cereals. Take-all is the chief of these. Dr. Garrett's work on it has already shown that oats are almost immune from infection and that the soil reaction is an important factor in its incidence on wheat. It is suggested that the disease is favoured by soil conditions which prevent the accumulation of carbon dioxide around the roots. One of the main objectives of the present investigations is to ascertain the source of infection of the wheat crop.

Another parasite of cereal roots, *Fusarium culmorum,* has been investigated by Mr. Samuel and Dr. F. J. Greaney who found it commonly present on wheat in slightly alkaline clay soils in various localities without doing appreciable damage. This is in contrast to the injury which this fungus can cause especially in the north of England, and the causes of this variability in the parasitic activity of this fungus remain to be determined.

Miss M. D. Glynn has discovered the presence in England of several fungus parasites of wheat not previously known to occur in the country. One of these, *Cercosporella herpotrichoides,* is a cause of serious losses on the Continent and in parts of the United States, but it has not hitherto done much injury in Great Britain, so far as is known. Miss Glynn also keeps records of the prevalence of diseases on the crops grown on the farm and publishes an annual report on their incidence, and a special grant is made by the Ministry of Agriculture and Fisheries for the continuation of work on the wart disease of potatoes (*Synchytrium endobioticum*) on which she has been engaged for a number of years.

Long Ashton Research Station.

The research mycologist at this station, Mr. R. W. Marsh, is an active member of the team engaged in studies on insecticides and fungicides, the work of which has been referred to earlier (p. 137). The advisory mycologist of the Bristol Province, Mr. L. Ogilvie, who is also placed at the station, is specially interested in the diseases of vegetables.

Mr. Marsh has done outstanding work on apple scab (*Venturia inaequalis*) and on improvements in the technique of the control of this disease. The visiting Sub-Committee whose Report was adopted by the Council in November, 1936, referred particularly to the excellent work done in collaboration by Mr. Marsh, Dr. Martin, Dr. Swarbrick and Dr. Kearns in such matters as the use of combined insecticidal and fungicidal washes and the methods of applying protective sprays to apple and other fruit trees. In addition, Mr. Marsh was working on the control of blackberry stem rust (*Kuehneola albida*), on the cause of root rotting in the strawberry, and on the action of substances used for the protection of pruning and other wounds in fruit trees; the last-named investigation and other pathological research is facilitated by the establishment, with the aid of a grant from the Council, of a new fruit plantation to be used primarily for pathological experiments.

Mr. Ogilvie has practically completed a survey of the chief diseases of vegetable crops in the Province in which he has been assisted at first by Mr. P. W. Brian and recently by Mr. C. J.

Hickman. In the course of his advisory and survey work Mr. Ogilvie encounters various pathological problems which are of concern to growers; such of these as time permits he takes over for further study at the station. Amongst these he had investigations in progress at the time of the Sub-Committee's visit on virus diseases of lettuce, rust of mint, (*Puccinia menthae*), halo blight of dwarf beans (*Bacterium medicaginis* var. *phaseolicola*) and wilt of hops (*Sclerotinia sclerotiorum*). Studies of the varietal resistance of dwarf beans to anthracnose (*Colletotrichum lindemuthianum*) have since been taken up; two varieties, Princess and Hundred for One, remained unaffected in spite of unusual prevalence of the disease in 1936. Complete control of mint rust was obtained in the same year by immersion of the runners in hot water at 105° to 115° F. for ten minutes at the period in mid-February when the mycelium of the fungus was present in the roots. Studies on several diseases of peas and other plants caused by species of *Fusarium* are in progress. The Sub-Committee recommended the provision of additional glasshouse accommodation for Mr. Ogilvie's use, especially for his work on virus diseases.

Dr. Swarbrick and Mr. Berry of the pomology department have carried out an interesting study of the incidence and spread of the reversion disease of black currants (believed to be due to a virus) in connection with the possibility that it may be carried by the mite (*Eriophyes ribis*) which causes the condition known as big bud. The results showed a connection between the occurrence of reversion and big bud and suggested that *Eriophyes ribis* is a vector of the former; but if so it would appear necessary to assume that the mite may be present and capable of spreading reversion for several seasons before it produces the characteristic big buds on the bush.

East Malling Research Station.

Dr. H. Wormald is in charge of the section of Mycology and Bacteriology at the station, while Mr. R. V. Harris of the same section is a recognised authority on the virus diseases of small fruits. Mr. M. H. Moore and Mr. H. B. S. Montgomery are the mycologists attached to the group of workers on insecticides and fungicides.

When the Council's visiting Sub-Committee reported in 1936, Dr. Wormald was mainly concerned with the diseases of top fruits such as the brown rots of apples, pears, plums and cherries caused by species of *Sclerotinia* and the bacterial diseases of plums and cherries. His work on the brown rots is widely recognised as amongst the most complete in existence on this group of fruit diseases. During 1936 he investigated the wastage of stored plums due to rotting by *S. fructigena* and *S. laxa* and made recommendations for its prevention. He also carried out studies of the sooty blotch disease of apples and plums caused by *Gloeodes pomigena*, which was unusually prevalent that year, as also in 1927. Cool wet weather favours this disease, to which Bramley's Seedling apple is very susceptible while in plums it was most conspicuous on Warwickshire Drooper and Pershore Egg. Treating the fruit after picking with a dip in a solution of bleaching powder, with subsequent washing, was effective in removing most of the blemish. Much work has been done on apple scab, especially in the improvement of routine measures of control and on the relationship between manurial treatment and the incidence of the disease.

Two bacterial organisms, *Pseudomonas mors-prunorum* and *Ps. prunicola*, are responsible for considerable damage to plum and cherry trees and much work on them has been carried out by Dr. Wormald in recent years. In sweet cherries both organisms have been found causing cankers on the stems, wilting of the young shoots, leaf spots and fruit blemishes. The susceptibility to infection of a number of sweet cherry varieties has been tested; Frogmore was the most resistant of these to cankering. Gummosis is a conspicuous feature of the disease in cherries, in which foliage infection is more severe than in plums. Much work on the control of this disease is in progress. Applications of Bordeaux mixture in both autumn and spring cause a reduction in the number of new cankers and infected buds formed. A third organism is the cause of a bacterial leaf spot of Morello cherries, and it is probable that there are other hosts in the genus *Prunus* and allied genera on which these bacteria will grow. A series of experiments carried out in collaboration with Mr. F. H. Beard showed that the plum canker due to *Ps. mors-prunorum* is less severe in trees receiving reduced amounts of phosphatic fertilisers, and that excessive applications of phosphate and potash are to be avoided where the disease is prevalent. Some work on the crown-gall of apples and other plants caused by *Bacterium tumefaciens* is also in progress.

Mr. Harris has contributed extensively to knowledge of the fungus diseases of raspberries but is now mainly engaged in the work on the virus diseases of strawberries and raspberries referred to in another section of this Report (p. 127). In a study of the wilt of hops caused by *Verticillium alboatrum,* Mr. Harris found that the disease was most severe under certain not yet clearly defined soil conditions probably associated with impeded drainage, and that it appears to be almost confined to the Fuggles variety.

Mr. Moore has tested various methods of controlling the strawberry mildew caused by *Sphaerotheca humuli* in plants already infected. Spraying with lime sulphur every two or three weeks during the period of spread of the disease was found adequately to protect the new foliage.

The Welsh Plant Breeding Station, Aberystwyth.

Professor Stapledon, the Director of the Welsh Plant Breeding Station, is Professor of Agricultural Botany in the University College of Wales. Miss K. Sampson, Lecturer in his Department, has made use of the exceptional facilities provided by the Station for research on certain diseases of oats and of pasture grasses and clovers. In some of this work Mr. D. W. Davies, the advisory mycologist at Aberystwyth, has also taken part. Of recent years much of Miss Sampson's time has been given to the investigation of *Epichloe typhina,* a parasitic fungus capable of living within the tissues of cocksfoot, *Festuca rubra,* and other grasses without causing obvious injury until it fructifies and destroys the inflorescence. Sometimes it produces barrenness even without fructifying or it can remain for several years and be propagated in clonal lines of the grass without causing obvious injury. A fungus of unknown affinities is commonly found in the ryegrasses, in which it causes no recognisable disease. Recently a second fungus with the same ability to live within its host plant without injuring the latter has been found in perennial ryegrass, and like the first can be transmitted in the seed. Work on oat smuts was carried out in 1935 by Mr. J. H. Western under Miss Sampson's supervision, especially a study of the reaction of smut-resistant varieties to strains of the parasites. This showed that resistance is sometimes due to a reaction of the epidermal cell wall, sometimes to a necrosis of the oat cells and sometimes to something in the tissues which retards the growth of the fungus.

In 1937 the Agricultural Research Council recommended a grant of £400 for one year to enable Mr. Western to undertake a survey of the fungus diseases of herbage grasses and clovers in Great Britain in collaboration with Miss Sampson, and to continue with her the work on *Epichloe typhina.* He commenced work under this grant in February, 1937, and was able during the following spring and summer months to examine the foliage diseases in the Aberystwyth pasture plots and to commence a survey of the chief diseases of importance to grass and clover seed growers in England, Scotland and Wales. This showed the prevalence of fungal diseases caused by species of *Helminthosporium*, especially in the ryegrasses and fescues. Experimental work on these and on the *Epichloe* disease of cocksfoot has been commenced by Mr. Western.

Horticultural Research Station, Cambridge.

The mycologist of the station, Mr. G. H. Brenchley, is engaged mainly in intensive studies of finger-and-toe disease (*Plasmodiophora brassicae*). These include direct tests of control measures and studies of the conditions determining the incidence and intensity of the disease. Evidence has been obtained that there is a certain seasonal periodicity in the disease, apart from the periodicity due to the age of the spores. There seems to be an optimum period for infection in the early summer. Under good conditions most of the infections seem to occur within 24 hours of planting. There is some suggestion that the intensity of infection may be affected by the presence of other soil organisms, bacteria and the like. The influence of environmental conditions on varietal susceptibility to the disease was also under study at the time of the visit by a Sub-Committee of the Council, whose Report was adopted in November, 1936. The two varieties of Brussels sprouts, Nos. 33-1 and 32-6, bred at the station are both fully susceptible under certain conditions but in the field the latter normally gives a reasonable crop while the former may be completely destroyed.

Direct control tests are in progress in collaboration with Dr. R. M. Woodman and include trials of compounds of mercury, copper, zinc and various alkaline substances as soil treatments.

In accordance with the recommendations of the visiting Sub-Committee provision has been made for the establishment of closer contacts with growers so that growers' problems of importance may be studied by Mr. Brenchley as far as his work on finger-and-toe permits.

The Experimental Research Station, Cheshunt.

General work on the diseases of glasshouse crops at the Experimental and Research Station is in the hands of Mr. P. H. Williams, while Dr. G. C. Ainsworth is responsible for work on virus diseases, Mr. H. L. White for that on vegetable diseases and Miss E. Oyler for the study of diseases of flowers. The virus work is separately mentioned in the section of this Report on virus diseases of plants (p. 126). In the investigations of rose diseases, for which the station receives financial aid from the National Rose Society, Mr. O. B. Orchard, the Extension Officer, collaborates with the mycological staff. Dr. W. F. Bewley, the Director, has himself established a position as one of the leading authorities on the diseases of glasshouse crops, including virus diseases, and on such allied subjects as soil sterilisation.

Mr. Williams is engaged in an investigation of the cause of cucumber root rot, which was severe in 1935-6. The predominant fungi associated with the rotting seem to be species of *Fusarium,* which have also been found to occur in the manure and may perhaps come from this source. He is also making a detailed study of rose rust caused by species of *Phragmidium* in which it has been found that the strain from cultivated roses may belong to a distinct species since, from the wild hosts, only one strain (that on *Rosa laxa*) could infect garden roses and the fungus on the latter is morphologically somewhat distinct from the rest. Successful control of rose mildew (*Sphaerotheca pannosa*) is reported by Mr. Orchard to have been given by spraying with a bouisol white oil emulsion at three-weekly intervals.

Mr. White is investigating the crown rot of rhubarb the cause of which, though *Bacterium rhaponticum* may sometimes be obtained from diseased plants, is not yet clear. Glasshouse runner beans were severely attacked by halo blight (*Bacterium medicaginis* var. *phaseolicola*) in 1936 and control of the disease was found to be largely dependent on the use of seed free from infection; this crop also suffers from the attacks of various soil fungi (*Fusarium, Phytophthora,* etc.), the control of which is under study.

Miss Oyler has been working on diseases of marguerites, verbena and *Solanum capsicastrum* caused by species of *Phytophthora.* These fungi are capable of attacking tomatoes, an important matter where so much of the glasshouse accommodation is devoted to tomato growing.

The diseases of carnations are at present under investigation, growers' enquiries having shown that they are causing considerable trouble. Mr. White has worked on the control of the carnation wilt caused by *Verticillium cinerescens,* which he has found to be transmitted in cuttings from diseased plants. The use of lime, with sterilisation of the top soil, appears to promise successful results. The fungus has so far not been found to attack other plants and it may be possible to clear the soil by rotation with several crops of tomatoes.

In the mushroom work recently undertaken at the station attention has been directed to the control of the diseases that sometimes ravage the beds. The early work was of importance in showing that diseases of the mushroom crop can be carried in the casing soil; this has led to the use only of sterilised soil for casing. Mr. Williams has found an invader of the beds new to England in a fungus, *Pseudobalsamia microspora,* which can rapidly become a troublesome " weed ". He has also studied the conditions under which the serious mushroom parasite, *Oospora fimicola,* flourishes, finding that it is favoured by alkalinity and a certain stage of decomposition of the manure.

Preliminary experiments carried out by Mr. W. H. Read on the cause of the spotting of tomato fruits called " water spot " at Covent Garden indicated that it is associated with the presence of spores of *Botrytis* in the droplets of water that form on the fruit under conditions leading to " sweating ". Further work on this blemish has been undertaken.

Flower disease research at Seale Hayne Agricultural College.

In 1936 the Agricultural Research Council made a grant of £175 to supplement a contribution from the Great Western Railway to the Penzance Flower and Vegetable Committee of the National Farmers' Union for work at Seale Hayne Agricultural College on the diseases of flowers in the south-west of England. The grant was increased to £220 for the calendar year 1937.

The work is in the hands of Dr. P. H. Gregory, who receives advice from a small committee of growers and research workers appointed by the Penzance Committee; it is carried out in liaison with the advisory officers attached to the College. The Sub-Committee whose report on their visit to the College to see the broccoli breeding work there was adopted by the Council in November, 1936, were able to see Dr. Gregory's work as well as the allied investigations carried out by Mr. A. Beaumont, Advisory Mycologist for the South-Western Province. They considered that the investigations were directed to clearly defined and practical aims, that the College was well situated as a centre for work of this nature, and that such research is particularly required at the present time if markets like Covent Garden are to be satisfied that they can get as good produce from the home grower as from abroad.

At the outset, work was concentrated mainly on the leaf diseases of flowers of economic importance in the south-west. Narcissus, iris, anemone and tulip plants all suffer to a greater or less degree from fungus diseases of the leaves, while narcissus and iris are also affected by diseases believed to be caused by a virus.

Extensive trials have been made on a number of varieties of narcissus with a view to controlling the leaf diseases caused by fungi. White mould (*Ramularia vallisumbrosa*) has been well controlled by certain sprays, which however, are only effective against secondary spread of leaf scorch due to *Stagonospora curtisii* since the primary infection by this fungus may already have taken place before the shoots emerge above ground; picking off the infected leaf tips gives the best control of this form of the disease. " Fire " (*Botrytis polyblastis*) was also controlled by spraying and the destruction of diseased foliage. Studies in the life history of the white mould fungus have indicated that it is carried over from season to season in the form of resistant selerotia on the old leaves, from which spores are produced about the time when the new shoots appear above ground.

Tulip fire (*Botrytis tulipae*) has proved difficult to control by spraying. One of the chief anemone troubles is the " browning " disease, the cause of which is under study. Iris varieties sometimes suffer so much from the suspected virus disease as to be rendered unprofitable. Certain varieties of narcissus suffer severely from stripe, a disease believed to be also due to a virus; hot water treatment has not given control of this conditions, against which roguing out of diseased plants appears to be the only practicable measure.

The Universities and Colleges.

Most of the important investigations on plant diseases due to bacteria and fungi in progress at the Universities and other academic centres is outside the scope of this Report. In some cases, however, the Agricultural Research Council have made grants for special researches which it appeared could be best done at such centres.

At Cambridge the work on the chocolate spot of broad beans referred to in the Council's last Report was continued with further grant aid from the Council's funds until the 30th September, 1936. Dr. A. R. Wilson's investigations showed that chocolate spot, previously thought to be a bacterial disease, is in its commonest and most destructive form caused by the fungus *Botrytis cinerea.* He found that there were two types of attack, an " aggressive " attack which kills the shoots or even the whole plant and is the consequence of a massive infection by spores and a prolonged period of favourable weather for successful parasitism of the fungus, and a " non-aggressive " attack causing the common discrete chocolate-coloured spotting, which occurred when spores were fewer and conditions less favourable. For infection to take place a film of water must be present on the leaf or stem; infection occurs most rapidly when the temperature is about 20° C. Air movement influences infection, mainly by its action in evaporating the water on the green parts of the plant. A heavy rainfall or sufficiently prolonged high atmospheric humidity is the major factor in inducing epidemic attacks, such as occurred in 1935 during the critical period from April to July. For the study of the epidemiology of the disease special apparatus was designed and constructed in which temperature, humidity and the like were controlled. The same fungus was found causing a similar disease in the common vetch, *Vicia sativa,* and milder symptoms in lucerne and sanfoin.

Another investigation supported by the Council with a grant to the Botany School, Cambridge, was on the " watermark " disease of willows. The cricket-bat willow, which is the variety chiefly affected, is extensively grown by farmers in the eastern counties. Watermark disease was causing such losses that the eradication of affected trees has been made compulsory in certain areas by an Order under the Destructive Insects and Pests Act. The evidence that diseased trees are a menace to healthy ones in the neighbourhood was to some extent circumstantial. Work carried out in Holland indicated that an allied disease in that country was transmitted by insects, and it became desirable to ascertain to what extent the two diseases were similar and similarly conveyed from diseased to healthy trees. In consultation with the Forestry Commission, who had supported the earlier investigations, the Agricultural Research Council made a grant of £200 to provide for the continuation of Mr. E. McC. Callan's entomological investigations under the supervision of Dr. W. J. Dowson on the transmission of the disease, from September 1936 to March, 1937. After a general survey of the insects that might be implicated in conveying the disease, Mr. Callan concentrated attention mainly on the gall midges (*Rhabdophaga* spp.), a sawfly (*Euura atra*) and a weevil (*Cryptorrhynchus lapathi*). The results of the tests with these insects, mainly with one of the gall-midges and the sawfly, which are thought to be the most likely vectors, are not expected until 1938 or 1939. The possibility that birds may occasionally spread the infection, since tits in particular rip open the willow shoots in search of insect larvae, is also being investigated. Other work, carried out in conjunction with the East Anglian Institute of Agriculture in Essex, includes a study of varietal resistance to the disease and of the effect of using sets from diseased trees. The Cambridge work has confirmed that watermark disease is caused by *Bacterium salicis* and not by *Pseudomonas saliciperda*. to which the Dutch disease is attributed, and has shown that the white willow (*Salix alba*) can also be attacked.

At the Imperial College of Science and Technology, investigations of certain diseases of lettuce have been in progress under the supervision of Professor W. Brown. One of the most serious of these is that caused by the fungus *Marssonina panattoniana,* which is responsible for much of the poor condition of lettuce crops wintered in the open. It is less troublesome on the so-called spring crop, which is wintered in frames and planted out in the spring. Towards the intensive investigations of this disease the Agricultural Research Council made a grant to the College of £300 for the academic year 1936-7 and have made a similar provision for its continuation during the current year. The work aided by these grants is carried out by Miss G. Stevenson, under Professor Brown's direction, and is mainly field work, based on previous laboratory studies and small scale experiments. It is carried out in co-operation with several growers, and covers detailed observations of the conditions favouring the disease, its progress in different seasons and under different conditions of cultivation, its rate and method of spread, and its control on the growers' land. The use of clean uninfected seed has proved to be the essential factor in the production of healthy crops, and the methods of growing seed-bearers free from disease and of disinfecting the seed worked out at the Imperial College Field Station at Slough have given excellent results so far as they have been tested. Laboratory work on the influence of temperature and humidity on the incubation period after infection and on the viability of the fungus on lettuce debris and in the soil is also in progress. The effective control of this disease, which is considered to be the limiting factor to the successful cultivation of winter lettuce in the south of England, might do much to restore the waning popularity of this crop.

Another investigation at the Imperial College supported by grant aid from the Council is that on certain bacterial diseases of plants carried out by Miss M. S. Lacey under the direction of Professor S. G. Paine. The Council provided a sum of £198 to supplement a grant of £52 from the Ministry of Agriculture and Fisheries during the academic year 1935-6 and a further grant of £252 for the following year, when it was proposed to investigate in particular the so-called "cauliflower" disease of strawberries and allied diseases of chrysanthemums, sweet peas, violets, carnations and other plants. In 1935 Miss Lacey obtained evidence that the fasciation sometimes observed in sweet peas could be induced by infecting the plants with strains of a bacterium isolated not only from sweet peas but from a number of other plants showing certain disease symptoms. These diseases, variously characterised by dwarfing, fasciation, and bunching of the shoots at the base of the plant (the so-called "leafy gall"), are reported to be increasing in prevalence in certain areas such as the south-western counties and parts of Middlesex. Some of them, particularly the cauliflower disease of strawberries and dwarfing disease of violets, have been attributed to or confused with diseases caused by eelworms, and if effective control is to be secured it is important to know their true nature. The strawberry disease has been attributed to the nematode worm, *Aphelenchus fragariae,* which also causes the red plant disease of this crop, but Miss Lacey's work showed that affected plants contained the same bacterium as was found to be the cause of fasciation in the sweet pea. It is probable that "cauliflower" is a bacterial disease and unlikely that it can be controlled by measures taken against the eelworm. Eelworm injury to chrysanthemums is controlled by the hot water bath treatment, but this is not effective against the destructive leafy gall disease due to the bacterium in question, though it may be possible to find a combined treatment for the two diseases. In addition to her extensive work on the bacteriology and parasitism of this organism, which is considered to be identical with *Bacterium fascians,* Miss Lacey has examined and reported on various cases of bacterial plant diseases sent in by plant pathologists elsewhere.

Mycological work at advisory centres.

Though the work of the advisory mycologists in England and Wales, where mycologists are attached to all the provincial advisory centres, and in Scotland, where this subject is dealt with by the headquarters staff of the Department in Edinburgh and by the advisers in plant husbandry at the Glasgow and West of Scotland Agricultural College centre, is mainly advisory and demonstrational, still a considerable amount of experimental and some definite research work is done by the advisers. Some of these hold University or College posts in addition to their advisory duties, but it is scarcely advantageous or, indeed, practicable to distinguish between the investigations carried out in these two capacities.

An extensive scheme of trials of disinfectants for the control of finger-and-toe disease (*Plasmodiophora brassicae*) is in progress at a number of centres. While lime remains the best known and most frequently applied antidote for this disease, its action is irregular. Mercuric chloride is more reliable and is especially useful in the seed bed. Extensive experiments on seed disinfection for the control of various seed borne diseases are in progress at Aberystwyth (cereal smuts), Cambridge (cereals, peas, etc.) and Glasgow (oat diseases). At Cambridge, Dr. Dillon Weston has carried out studies on the relation between the molecular constitution of the fungicide and its toxic action. He has also investigated the conditions leading to sporulation in certain dark-spored fungi (*Helminthosporium* and *Alternaria*) and found that the production of spores is stimulated by intense light.

Research on the diseases of hops has been carried out by the advisory mycologists at Wye College for many years. The studies of Professor E. S. Salmon and Dr. W. M. Ware on hop downy mildew (*Pseudoperonospora humuli*) are classical, while their investigations of other hop diseases continue to give results of great practical and scientific value. The control of downy mildew by spraying has gradually become established, and the Wye studies on the mode of transmission of the many virus and other diseases of this crop that have been investigated there are of great importance to growers. In addition to the hop work, Professor Salmon has carried out, in collaboration with the Chemical Department, extensive studies on the fungicidal properties of a large number of substances. Dr. Ware has done much work on the fungus diseases of mushrooms.

At the Midland Agricultural College the advisory mycologist, Mr. H. H. Stirrup, has concentrated on the investigation of sugar beet diseases, whether caused by viruses, fungi or physiological disorders. At Seale Hayne Mr. A. Beaumont is collaborating in the work on flower diseases mentioned earlier in the Report (p. 164) and is continuing observations on the seasonal occurrence of potato blight in relation to certain meteorological conditions, on which he had been engaged for a number of years. Work on flower diseases is also in progress at the Reading advisory centre where Mr. W. Buddin, the advisory mycologist, has studied certain tulip diseases. Experiments extending over several years have shown that the grey bulb rot due to *Sclerotium tuliparum* can be effectively controlled by soil sterilisation by steam or the admixture of a suitable fungicidal powder in the top layers, or by planting the bulbs with their " noses " projecting well above ground. The disease termed " shanking " can be caused by either *Phytophthora erythroseptica* or by *P. cryptogea,* while an allied though less severe disease recently described by Mr. Buddin with Mr. W. C. Moore of the Ministry's laboratory at Harpenden is caused by a species of *Pythium.* Mr. Buddin is co-operating also in the investigation of the problems of degeneration in strawberries already referred to (p.). Dr. F. T. Bennett, the adviser at Newcastle, is a leading authority on the diseases of turf; he has recently found that the disease of lawns, golf greens and the like, known in the United States as " dollarspot ", is prevalent in Great Britain, and has carried out a detailed study of its cause. It is due to a previously undescribed fungus, which Dr. Bennett has named *Sclerotinia homoeocarpa,* parasitic on the fine lawn species of *Poa, Festuca* and *Agrostis.* He has also done much important work on the *Fusarium* foot rots of cereals.

During the period under review the importance of boron as a necessary element in the growth of plants, certain of which are very sensitive to its deficiency, has become fully recognised and valuable tests in the control of diseased conditions such as brown heart or " raan " in swedes have been carried out at Glasgow, Bangor and elsewhere. At Bangor, Dr. T. Whitehead found marked differences in susceptibility to brown heart among different varieties of swedes. At Leeds Dr. W. A. Millard has continued the investigation of internal rust spot of potatoes and carried out experiments on the control of grey leaf of oats by manganese.

Ordinarily the work of the advisory mycologists is outside the scope of this Report. The above brief catalogue of their research and experimental activities shows, however, that they contribute substantially to the body of State-aided investigation of the diseases of crops. No survey of the progress of agricultural research carried out by the aid of Government grants would be complete without some reference to their work, which is financed mainly from the Development Fund.

HELMINTHS OF ECONOMIC IMPORTANCE (PLANTS SECTION).

Researches on plant-parasitic Helminths and the diseases they give rise to are being pursued at a number of research centres in Britain. Investigations cover a wide field despite the recent concentration on problems relating to *Heterodera schachtii.*

Several lines of approach present themselves with regard to the elucidation of problems relating to each species of parasite, and, while a wide range of investigations covering many aspects of the prevention and control of eelworm diseases of plants is being carried out at the larger research centres, individual workers in other districts specialise on those lines best suited to the material and facilities available. Thus field-scale experiments based on the same initial laboratory studies are carried out in many different districts at the same time; it has become clearly indicated, however, in the publications describing such work, that much of the advantage which should be gained by such experiments being carried out simultaneously under diverse soil, climatic and agricultural conditions is obscured by the lack of reliable and standardised methods of technique. New methods of technique are now being devised and these, together with improvement and standardisation of old methods, should prove of the greatest value.

For the purposes of this Report the researches in progress can most conveniently be dealt with in two sections, the first comprising investigations into diseases caused by species of the genera *Anguillulina, Aphelenchoides* and other closely related genera, the second dealing exclusively with *Heterodera schachtii.*

The genera Anguillulina and Aphelenchoides.

At the Institute of Agricultural Parasitology Dr. T. Goodey has continued his researches on the genera *Anguillulina* and *Aphelenchoides.* Details of a valuable method of technique which enables stained eelworms to be demonstrated within the tissues of shoot-structures of the host plant have recently been published. By the use of this method intensity of infection can now be accurately estimated. This technique has already furthered Dr. Goodey's investigations on the varietal susceptibility of oats to *Anguillulina dipsaci,* the causal organism of " tulip-root ". Two varieties of oats have, as a result of trials covering a period of three years, been shown to possess a definite resistance to attack. New hosts of *A. dipsaci* have been investigated and recorded.

Dr. C. L. Walton of Long Ashton Research Station has investigated the cause of outbreaks of "tulip-root" in oats after periods of rotation in excess of the time normally required to "starve out" the parasite. Negative results have followed attempts to produce infection from seed harvested from infected crops but weeds have been shown to act as reservoir hosts during the cultivation of non-susceptible crops. Mr. L. R. Johnson's finding at Leeds that *Galium aparine* and *Stellaria media* can act in this manner has been confirmed and two additional host plants, *Veronica agrestis* and charlock (*Brassica sinapis*) have been recorded. The mode of infection of sugar beet by a strain of *A. dipsaci* is being studied at the Midland Agricultural College by Mr. A. Roebuck. Mr. Johnson has carried out work at Leeds on the part played by *A. dipsaci* in the causation of crown rot of rhubarb, and its significance in relation to the strain attacking oats. Dr. Walton found that one of the several distinct types of parsnip canker occurring in the Evesham district of Worcestershire was associated with infestation by this worm. The attack often develops when the swollen root is quite small and its effect is to cause considerable irregular hypertrophy and cracking on the crown of the mature root, with lesions containing the parasite on the leaf-stalks and leaves. Moderate dressings of cyanamide failed to check infestation. Dr. E. E. Edwards (Cardiff) has investigated severe damage caused to primulas during 1937, with special reference to the susceptibility of different species and methods of dispersal of the parasite. Hot water treatment of bulbs infected with *A. dipsaci* is under study at Seale Hayne Agricultural College by Mr. L. N. Staniland and at Reading by Mr. W. E. H. Hodson. The control of *Aphelenchoides ritzema-bosi* by hot water treatment of chrysanthemum rootstocks has been the subject of further studies at Cardiff, Reading and Long Ashton. Mr. Hodson of Reading is also investigating a recently discovered eelworm *A. hodsoni,* which is parasitic in narcissus bulbs.

Researches on Heterodera schachtii.

Researches on various biological strains of *Heterodera schachtii* are reported from nine centres during the past year. Many aspects of the prevention and control of this parasite are being studied. For convenience and clarity these researches are described below under two sub-heads, (*a*) Biological investigations, (*b*) Chemical investigations.

(*a*) *Biological investigations.*—At the Institute of Agricultural Parasitology Miss M. Franklin has shown that free larvae of the potato strain of *H. schachtii* survive and retain the power of entering the host after a period of nine months out of doors and sixteen months indoors. As a means of biological control she has shown that the cultivation of maize for one season on land infected with this strain, reduces the viability of the cyst content by 35 per cent. by inducing the larvae to hatch in the absence of a suitable host, whereas the reduction in the control plots where lupins were grown was only 16 per cent. Experimental trap-cropping with potatoes as a means of eliminating eelworm from infested land is in progress. Methods of treating "seed " potatoes to kill adherent cysts which might serve to distribute the parasite to clean land are being tested. Studies on the host-ranges of strains attacking oats, peas, beet and certain weeds, to elucidate the possibility of reservoir hosts during rotation periods, and on cases of apparent host-transference, are being continued.

Experiments are being conducted at the Craibstone Farm of the North of Scotland Agricultural College, Aberdeen, by Dr. D. Robertson, on the varietal resistance of potatoes to the effects of eelworm infestation.

Dr. H. W. Miles, of the University of Manchester, has initiated a general survey of the soils in the North-western Province for the distribution of eelworm cysts. Most soils which have been under arable cultivation at some time within the last 15 or 20 years have proved to contain cysts. Observations on the rotation of crops in relation to eelworm attack, including the effects of continuous cropping with potatoes, prolonged absence of potatoes, and selected rotational crops, have been continued, and it has been shown that an eight-year break is sufficient to enable land to recuperate from eelworm attack. At the University of Leeds, Mr. Johnson and Mr. H. W. Thompson have tested mercuric chloride for the control of potato sickness. Both in solution and as a dry dressing this compound increased yields despite a toxic effect on the early growth of the plants. Laboratory experiments showed that the eelworms were retarded in hatching, not killed, by the treatment. Similar treatment of tomato sick soil gave satisfactory control of the disease. Cultural measures for the reduction of tomato sickness have also been described by these workers.

A survey to discover the distribution of the beet strain of *Heterodera schachtii* is being carried out by Mr. F. R. Petherbridge of the Cambridge School of Agriculture, who is also carrying out experiments and observations to decide the effects of different crops and weeds on the eelworm content of soils and the degree of infection which brings about " beet-sickness " in different soil types.

At the Midland Agricultural College Mr. Roebuck is continuing field experiments with a view to controlling the potato-strain of *H. schachtii* by soil dressings, trap-cropping and the addition of root excretions or plant extracts. Similar tests may be carried out in future on land infected with the beet strain. The distribution of a strain attacking swedes on the Wolds of Lincolnshire, discovered in 1936, is being investigated.

(b) *Chemical investigations.*—Researches have been continued at the Institute of Agricultural Parasitology on the effects of certain chemical substances applied to soil, which, in previous small-scale experiments had suggested the possibility of controlling " potato-sickness." It had been shown by pot experiments carried out by Dr. R. H. Hurst in conjunction with Dr. Marjorie Triffitt, that calcium cyanamide applied in sufficient quantity and thoroughly mixed with the soil was lethal to the contents of cysts of the potato strain of *H. schachtii.* From these experiments it appeared probable that dressings applied in the autumn would prove as effective as dressings applied in the spring. Field trials indicated that, owing to the difficulty of producing an intimate mixture of the chemical with the soil, heavier dressings were necessary in the field than in pots. The results of field experiments of 1936 carried out in Lincolnshire have been published. At Potton, Bedfordshire, field trials are being continued by Dr. Hurst and Miss M. Franklin, using dressings up to four tons per acre. Green crops were being grown in 1937, to be followed by potatoes next year. Experiments with ferric oxide have been discontinued as the favourable results of the first experiments were not later maintained. In the field heavy dressings of calcium cyanamide have produced an increased yield of potatoes, while the number of new cysts formed has been relatively small as compared with numbers on the control plots. Potatoes are again being grown on the 1936 " cyanamide plots " without further treatment except the addition of the usual artificials, but it appears unlikely that yields from plots which received less than two tons of cyanamide per acre will be greater than yields from the control plots. Pot experiments on the effect of calcium cyanamide on oat and pea strains of *H. schachtii* were being carried out in 1937.

Field experiments on the use of calcium cyanamide as a means of controlling " potato-sickness " have been continued during 1937 in Wales by Dr. Edwards, of Cardiff. Dressings of ten to one hundred cwts. per acre are being used on land of contrasted soil types, with results, in general uniform, and comparable with favourable results of 1936 experiments. Attempts are being made to determine the best method and time of year for applying the dressings. Tests with other chemicals used in 1936 have been discontinued. Pot experiments on the oat and pea strains indicate that *H. schachtii* is the major cause of " oat-sickness " and " pea-sickness " although other contributory factors are almost universally present. Calcium cyanamide has given good results in stimulating growth, and (at over sixty cwts. per acre) completely retarding cyst-formation in the oat strain. Experiments with the pea strain indicate that calcium cyanamide, benzoquinone and a mixture of equal parts of calcium hypochlorite and calcium oxide are worthy of further trial.

From Long Ashton Research Station, Dr. Walton, Mr. L. Ogilvie and Mr. C. J. Hickman report that simple nitrogenous fertilisers and sulphate of potash have the same effect in the production of normal crops on land infected with the pea strain of *H. schachtii* as heavy dressings of calcium cyanamide. Increased yields of potatoes on " potato-sick " land were obtained following applications of both sulphate of ammonia and calcium cyanamide at three and ten cwts. per acre, but these increases were not correlated with cyst counts on the roots of the plants from treated land. Pot experiments are in progress to determine the effects of various fertilisers on the pea strain.

Investigations on the effects of certain fumigants on the oat strain of *H. schachtii* have been carried out at Rothamsted by Mr. W. R. S. Ladell. These showed a smaller increase of cysts in the soil following treatment with " Seekay " and carbon disulphide than occurred in the control plots. A real relationship between two variables, gross cysts numbers and yield of oats, was found when a comprehensive system of sampling was carried out. Experiments to compare the effects of rye-grass and smooth-stalked meadow grass (*Poa pratensis*) on the cyst content of the soil, both with and without fumigation, were being carried out during 1937.

A different type of chemical investigation is being carried out at Manchester University by Dr. R. Stewart in conjunction with Dr. Miles. The composition of the potato plant throughout the season on an area not heavily infested with eelworm has been determined. The maximum total absorption of N,K_2O, P_2O_5 and CaO per plant was found to correspond to the following quantities per acre:—N 192 lb., K_2O 222 lb., CaO 85 lb., P_2O_5 44 lb. Investigations on the effect of eelworm attack on heavily infested areas under diverse manurial conditions have shown that a heavy dressing of farmyard manure, or complete artificial fertiliser proved most satisfactory where infestation was particularly severe. Where intensity of attack was uniform the yields were depressed to the greatest extent in the absence of potash.

Work on the eelworms that attack plants is under the co-ordination of a Committee of the Agricultural Research Council which held five meetings during the period under review. As mentioned in the last Report the Council made a grant of £1,150 to the London School of Hygiene and Tropical Medicine spread over the two years from August, 1935, in order to extend and intensify the work on the potato eelworm at the Institute of Agricultural Parasitology, St. Albans. Miss M. Franklin was appointed under this grant to assist Dr. Triffitt in the biological investigations on *Heterodera schachtii* and was provided with an additional glasshouse and facilities for field investigations. Further arrangements have been made for the continuation of this work to the end of the financial year 1937-8 when the position will be reviewed. As also mentioned in the Council's last Report a grant of £700 was made to the School spread over two years from April, 1934, to provide for the continuation of Dr. Hurst's chemical investigations of the substances influencing the hatching out of the eelworm cysts and the toxic action on the cysts of various chemical compounds. Dr. Hurst was appointed to the permanent staff of the Institute of Agricultural Parasitology in April, 1936. He submitted a report to the Council in that year. Attempts to isolate and identify the active substance in the root excretion from potatoes which stimulates the hatching of the cyst resulted in obtaining a very active solid which, however, proved difficult to purify. As the active principle is present in the root excretion in very small amount, not enough was available for the further work of purification. At the same time other substances were found which possess the property of stimulating the cysts to hatch. Of these, various amino groups were noticeable, tyrosine being active in very dilute solution. Lysine in the form of its picrate was greatly stimulating and picric acid alone was lethal to the larvae at a strength of 1 per cent. and actively stimulated hatching at 0·01 per cent. Various compounds of iron proved toxic and urea in sufficient amount prevented the formation of new cysts. Urea is a decomposition product of cyanamide in normal soil, and dressings with the latter carried out by Dr. Triffitt showed that it was the only one of numerous artificial fertilisers tested that was lethal to the eelworm. In the further studies of the action of cyanamide Dr. Hurst is collaborating with Dr. Triffitt. The field work with this and with ferric oxide involved the sampling of the soil for cyst content and the experimental error involved in such sampling has been worked out.

For the work at Manchester University carried out by Dr. Miles and Dr. Stewart as described above, a special research grant of £220 per annum was made from the funds at the Council's disposal on the Vote of the Ministry of Agriculture and Fisheries from August, 1936. The grant has been renewed at the same rate for a further year from 1st August, 1937.

At their meeting in June, 1937, the Council's Committee recommended a grant not exceeding £100 per annum for work on the control of potato eelworm in Ayrshire under the supervision of Dr. D. J. O'Brien of the West of Scotland Agricultural College, to supplement funds provided for this work by the Potato Marketing Board and local farmers. The total amount received would provide for the appointment and expenses of a special assistant to Dr. O'Brien. Earlier work had indicated that the conditions of attack in the early potato cultivation of Ayrshire were somewhat abnormal, and had yielded results of promise in the control of the disease.

VI.—ANIMAL PHYSIOLOGY: NUTRITION AND BREEDING

Details of the more important research in progress at the Universities, University Colleges and Research Institutes in the field of animal physiology, are given in the following sections under the two main headings, Nutrition and Husbandry and Breeding.

ANIMAL NUTRITION AND HUSBANDRY.

Animal Nutrition Institute, Cambridge.

The Cambridge Animal Nutrition Institute covers a field of research much wider than its name suggests, and it is necessary to describe the activities of its staff under a series of heads.

In the Nutrition Department, large scale feeding experiments have been carried out with pigs to determine the influence of the level of the fat supply, an extension of work on the level of protein supply mentioned in the Council's last report.

This work is to a large extent a continuation of earlier researches on the digestibility and actual utilisation by pigs of three different grades of meat meal containing widely different proportions of fat. In these experiments it was shown that the meat proteins are as readily digested as those of white fish meal, and that the fat also was very fully utilised. The middle grade with 11 per cent. of fat proved the most digestible of the three.

Similar experiments on the chemical composition, digestibility and general nutritive value of potato meal and potato cossettes were begun and are in progress.

The sheep feeding standards drawn up by the late Professor T. B. Wood some years ago have often been questioned, and it is therefore natural that they should be re-examined by the Institute from which they originally came. These requirements presuppose a certain definite appetite for a sheep of a given live weight, and this appetite is expressed in terms of 1 lb. weight of dry matter of food consumed per day.

It has been shown that Professor Wood over-estimated the appetite considerably and that his figures should be reduced to 85 per cent. of their value to approach the truth. Furthermore, it has been shown that the appetite for typical winter food, hay, swedes and concentrates, is less than that for grass, even inferior grass, and greatly less (by some sixty per cent.) than that for good young leafy pasture. These differences imply corresponding changes in feeding standards. The results confirm in essence those found by Professor Scott Watson at Oxford.

The Department has also been engaged on fundamental work on ruminant digestion. In these animals all studies of nutrition are rendered difficult by the immense flora of bacteria which, living on the alimentary tract of their host, not only carry on their own metabolism, but also play a part ancillary to that of the digestive enzymes of the gut in the breaking down of ingested food.

The Department now possesses sheep in which through an opening known as a " rumen fistula " it is possible to extract food from the stomach at intervals and thus follow directly the course of digestion. Such studies must be interpreted by comparison with the results of experiments in which cultures of the bacteria are allowed to break down food in vitro; the department has therefore carried out such investigations.

Work on the nutritive value of lucerne was completed during the period. It has furnished data on the ratio of leaf to stem at different stages of growth, and the composition of the leafy and stemmy fractions. The leaf being the more valuable it is evident that those varieties of lucerne in which it forms a high proportion of the crop are the most desirable. The results of this investigation of varieties have been used in the consideration of the methods of conservation by artificial drying.

The composition, digestibility and nutritive value of Marrow stem kale and Thousand head kale have been investigated. It has been shown that the starch equivalent of 100 lb. of dry matter of either kale is very nearly that of 100 lb. of dry matter of swedes. But Marrow stem kale gives about 13·8 per cent. of dry matter, Thousand head kale reaching the very high value of 15·8 per cent. These figures are higher than those generally reached by swedes, so that in general one ton of either kale has a higher calorific value than a ton of swedes; in addition the kales are far better sources of proteins and minerals than the roots.

The Poultry Nutrition Section of the Department has carried out a varied series of investigations. The most fundamental work is that on the calorimetry of the fowl it is, in fact, the application to these birds of the method which laid the foundation of much modern nutritional work concerned with quantities (starch equivalent), and particularly of that of Professor

T. B. Wood. The preliminary experiments have shown that the apparatus is suitable for the work it has to do, and enabled its reliability to be judged. They have also shown that the effect of activity on metabolism is greater in fowls than in mammals, and that feeding, especially above the minimum necessary for maintenance, increases the activity and makes it irregular, so as greatly to increase the difficulty of determining the standing and sitting metabolic rate which is a fundamental measurement. It is hoped that these preliminary experiments will allow of definite work being undertaken soon.

Another fundamental investigation has for its object the determination of the nitrogen, calcium, phosphorus and sulphur balances, in fowls on diets differing in the amount of protein they contained. These show that there is a close linkage between the nitrogen and sulphur metabolisms and also between the calcium and phosphorus metabolisms.

Other work has determined the effect of intensive vitamin A administration on the vitamin content of the yolk of the eggs laid by a bird.

Further work has had more directly practical ends. The Section has devised rations which can be compressed into pellets of uniform weight; and has thus made it possible to carry out experiments in which the individual food consumption is accurately known. By this method estimates of the protein intake necessary for the maintenance and egg production of the laying hen are being made, and at the present time laying pullets are also under investigation.

The nature of the fat of fowls is of importance because of its influence on the palatability and keeping qualities of the carcase. Experiments have been carried out to determine the effect on these characters of feeding cod liver oil up to the time of killing, and the influence on the fat of different cereals in the fattening ration has also been investigated.

It has been shown that the " quality " of the egg is largely a function of the individual bird.

Finally analysis of samples of dried poultry manure have shown that part of the uric acid, which is the important nitrogenous constituent, is converted into ammonia and lost during the collection, drying and storage of such manure.

In the Chemical Department of the Institute Mr. Foreman has continued his investigation into the chemical nature of the carbohydrates present in the sap expressed from fresh grass leaves and other herbage. He has passed on to an investigation of the proteins which can be obtained from similar sources.

The work of the Departments of Physiology and Poultry Genetics, dealing as it does largely with problems of reproduction and genetics, is referred to in a subsequent Section of this Chapter (see p. 211).

School of Rural Economy, Oxford.

For some years Professor Scott Watson, with grants in aid from the Council, has conducted experiments on the relation between the intake of energy and live weight increase in sheep. In these experiments it was shown that for growing tegs Wood's standard for maintenance requirements of 9 lbs S.E. (starch equivalent) per 100 lbs. live weight per week was too generous. Scott Watson suggested that the energy intake of tegs at 9 to 12 months old should be:—6·5 lbs. S.E. per head per week for normal growth of $\frac{3}{4}$ lb. weekly, 9·7 lbs. for slow fattening, with a growth of 1$\frac{1}{2}$ lbs. per week and 15 lbs. for intensive fattening, when the growth is about 2$\frac{3}{4}$ lbs. per head weekly.

Following on these experiments in 1936-7 it was proposed to vary the quantities of protein and vitamins in the rations and for this purpose a capital grant of £50 and a maintenance grant of £110 were made from the funds of the Agricultural Research Council.

Rowett Research Institute.

The work of the Rowett Institute and its associated Duthie Farm has covered a wide range.

The Institute has for several years carried on over several generations a long term feeding experiment with rats. Fundamentally, the experiment involves the maintenance of two groups of rats derived from the Lister Institute's hooded rat colony and bred for three or four generations in Aberdeen. One group was fed on a diet representing closely that eaten by a working class population in Scotland. The other group received, in addition to this basal diet, a supplement of green food and as much milk as they cared to drink. Experiment showed that the unsupplemented human diet was inadequate for rats, one-third of the females dying during their second lactation. It was therefore supplemented by a restricted milk ration, the total of milk amounting to about $\frac{5}{8}$ of that of the experimenal diet.

The experiment was remarkable in that the food given varied from day to day throughout the week. The results showed that there was no appreciable difference in reproductive capacity between the two groups, but that rats on the supplemented diets grew faster and had a higher haemoglobin concentration in their blood. But the most striking difference showed itself in the result of an accidental infection with an organism of the *Salmonella* class which caused a gastro-enteritis from which many died. These deaths were " almost wholly " amongst the rats on the basal diet. Subsequent histological examination has shown the occurrence of curious lesions, akin in macroscopic appearance to human diverticulosis, in the older rats which died in this epidemic.

A somewhat similar experiment in which rats were fed on human diets derived from North and South India was interesting because each of these was deficient in calcium and phosphorus, and in one these elements were present in unsatisfactory proportion. As was expected, these rats grew slowly and suffered from imperfectly calcified bones and teeth.

The rat colony has also provided material for an interesting observation on the early lesions resulting from deficiency of vitamin A. They have shown that a degeneration in a special tract of nerve fibres in the brain stem is constantly present at a very early stage of avitaminosis and that it may be the first recognisable lesion.

The amount of calcium present in blood serum is a quantity of great importance in the maintenance of health; milk fever, for example, is associated with a low level of this element. It is therefore important to discover the effect of variations in diet on this quality, and the resulting clinical effects. The Rowett Institute has worked on this subject in sheep and cows. The results are of technical interest. The whole subject of the equilibrium levels of calcium and phosphorus in growing animals and adults, on deficient and unbalanced diets and on the distribution of these elements in the body is still under investigation in the Institute.

The Biochemical Department has determined the phosphorus content of West Australian cereals, and leguminous seeds; distinguishing between that present in phytin, in which it is unavailable to an animal which eats it, and the available residue. The Australian wheat and oats are much poorer in total phosphorus than English samples of these grains, and the amount actually capable of being utilised is still smaller. The leguminous seeds from West Australia have a much higher concentration of available phosphorus. The conclusion is reached that farmers should use bone meal or mineral phosphate in addition to calcium carbonate to balance cereal rations where skim-milk is not available.

The Institute has carried out experiments involving the maintenance of sheep on a phosphorus deficient diet, to which phosphorus-rich supplements can be added, to determine the effect of such treatment on the inorganic phosphorus, calcium, magnesium and phosphatan levels in the serum, and on the balance of these substances. The conclusion is that either dicalcium phosphate or steamed bone meal affords an adequate supplement but that phosphorus, fed as dicalcium phosphate, is utilised to an extent approximately 50 per cent. greater than that supplied as steamed bone meal. Further, dicalcium phosphate added as a supplement to a phosphorus deficient ration appears to exert a more favourable influence on nitrogen assimilation than does steamed bone flour.

Work at the Institute on iodine deficiency and thyroid disease is dealt with in a later Section of this Chapter (see p. 197).

The Institute has carried out an experiment with rats to determine the difference, if any, between the nutritive values of raw and pasteurised milk. The Duthie farm has added to this an experiment, duplicated at the Reading Dairy Institute on calves. The result is to show that there is no discoverable difference between raw and pasteurised milk as judged by their power of enabling rats or calves to grow.

An interesting new development on the work of the Duthie farm is that on the parasitic worms which inhabit sheep. This work depends on the possibility of rearing considerable numbers of lambs by hand, indoors, on an artificial diet which can be kept clear of all possible contamination with worm eggs. The farm has been singularly successful in this work, and has probably produced more worm-free weaned lambs than any other place in Britain.

One of the first experiments carried out with such lambs was designed to test the opinion often held that " salting " of sheep pastures reduced the infestation by parasitic worms of sheep grazing on them. Two groups of lambs were run in infested pastures, one treated with salt at about one ton to the acre, the other untreated; with this exception, all the conditions of management were the same. After fifty days all were slaughtered and the number of worms in the fourth stomach counted. In the case of one worm, *Haemonchus,* it appeared that the sheep put on salted pastures were significantly less infected than the controls, but the more abundant and more widely spread *Ostertagia* and *Trichostrongylus* were as numerous in one group of sheep as in the other. It thus appears that salting is not an effective method of controlling parasitic infestation.

The number of worms found in the individual lambs in this experiment varied very greatly, from 118 to 1,050, even the latter being a low number. It was discovered by a statistical investigation that the worm burden of these lambs has a significant positive correlation with the increase in weight which they show. The obvious explanation is that those lambs which grew fast did so because their appetites led them to eat more grass and hence more larval worms than those of their companions which grew less fast. This rather curious result led to an investigation of the number of worms to be found in the abomasum of the fat lambs sold from the commercial flock of the farm. Many of these lambs which appeared perfectly healthy and well finished harboured 3,000 or 4,000 individual worms of the genus *Ostertagia*. There was a marked difference in the relative numbers of the two worms *Haemonchus* and *Ostertagia* in lambs killed in May, July, August and September. In May the averages were no *Haemonchus,* thirteen hundred *Ostertagia,* in September an average of fourteen hundred of the latter were associated with five hundred *Haemonchus*. Another curious observation is that in mid summer, July, four single lambs had less than 250 *Ostertagia* whilst twin lambs had from 760 to 2,400 individuals of that genus; the difference would be explained by the fact that twin lambs, receiving less milk, are forced to graze more actively.

During 1937 the farm carried out a large experiment to determine the effect of diet on worm infestation, the results of which will be reported subsequently.

The Institute possesses a hill farm, Garrochoran, in Argyllshire on which it maintains a flock of sheep. These have been used, *inter alia,* for an experiment intended to examine the desirability of the practice current amongst hill farmers of sending down to the lowlands those ewe hoggs which are to replenish the breeding stock. The experiments afford a justification of the practice in that it proved impossible by the addition of supplements to the diet to keep such ewe hoggs on the hill in winter without an excessive mortality, and so severe a loss of condition that they never recovered their position during the next summer or in all probability during their life. The special cases in which it is impossible to winter ewe hoggs away may sometimes be met by more intensive cultivation of any arable land available; this possibility is being investigated by an experiment at Garrochoran.

The pigs on the Duthie farm have been carefully recorded for some seven years and these records of the numbers of pigs in each litter, the number reared and the weight at weaning have now been published. The conclusion is reached that there is no correlation between the number of pigs weaned per litter and the weight at weaning.

Pigs have also been used in a simple feeding experiment to determine the value of wheat in pig feeding. The conclusion reached is that unsatisfactory results are obtained when ground wheat forms more than 30 per cent. of the ration of young pigs, whilst in later stages (over 120 lb. live weight) up to 45 per cent. may prove satisfactory. The question of protein requirements is still under investigation.

The occurrence of a very serious outbreak of fowl paralysis amongst the flock on the Duthie farm led to a large experiment which is referred to in the section of the Report dealing with that condition (p. 267).

Nutrition and Disease.

As was recorded in the Council's last Report, the Committee which the Agricultural Research Council has appointed to consider the extension of research into nutrition in relation to disease was enlarged on the medical side in consultation with the Medical Research Council. Under the Chairmanship of Sir Frederick Gowland Hopkins the Committee has throughout the period now under review given close consideration to the best methods of advancing knowledge bearing on the question whether the resistance of animals to infectious disease, as distinct from those disorders which result from a deficiency of minerals or vitamins, can be strengthened by dietary adjustments. It need hardly be said that the problem is one of great complexity and difficulty, as has been shown by the researches of Dr. Marion Watson in the London School of Hygiene and Tropical Medicine, under the direction of Professor W. W. C. Topley of that School and Professor E. P. Cathcart of Glasgow University, on the influence of diet on the resistance of mice to infection. These researches have been in progress for some five years.

The Committee of the Agricultural Research Council did not submit recommendations until after the end of the two years covered by the present Report, but it may be stated that they devoted attention mainly to the major question of policy upon which the governing body of the Rowett Research Institute, Aberdeen, had sought the Council's advice. The governing body of the Institute felt some hesitation in extending work on nutrition in its relation to infection. They had no doubts as to the importance of the work, but they considered that if it were to be developed at the Institute, the arrangements should be such that it could, if that appeared to be the right course, be discontinued or moved elsewhere. The Council's Committee, of which Sir John Orr, the Director of the Rowett Research Institute, is a member, in examining this problem took into consideration the researches in progress at the London School of Hygiene and Tropical Medicine, the Veterinary Laboratory of the Ministry of Agriculture and Fisheries and the Moredun Institute of the Animal Diseases Research Association, and they conferred with senior members of the staffs of the Animal Nutrition and Pathology Institutes at Cambridge. They reached the conclusion that favourable conditions existed at Aberdeen for initiating at a comparatively low capital cost a scheme of research on laboratory animals prepared by Sir John Orr in collaboration with Professor J. Cruickshank of Aberdeen University and Dr. John Smith, City Bacteriologist at Aberdeen, whereby the resources of the University and City Bacteriology Departments could be combined with those of the Rowett Research Institute and co-operation with workers elsewhere could be maintained under the Council's Committee. The investigations, as Sir John Orr urged, would be regarded as being national rather than local in character and could at a later stage be transferred elsewhere, if that course appeared desirable. While it was proposed that one of the two bacteriologists employed should be Dr. Eleanor Anderson, a member of the Rowett Research Institute staff who has gained much experience in dietary studies on the rat, it was considered that the second bacteriologist should be appointed by the Council and be a member of the Council's scientific staff. Thus continuity of research could be maintained, wherever the next phase might be planned.

It was decided to leave to those who would be directly engaged in the investigations, acting in consultation with the Council's Committee, the decision as to whether the rat or the mouse would be the more suitable experimental animal. Among the considerations to which weight must be attached are, on the one hand, the knowledge already gained about the nutrition of the rat and the management of rat colonies at the Rowett Research Institute, and, on the other, the much greater body of information available regarding bacterial diseases of the mouse, and the facts that the mouse is easier to handle and less expensive to maintain in the large numbers which are statistically desirable and that it can readily be kept in conditions of sterility. If the rat is eventually chosen, preliminary work on the epidemiology of this animal will be necessary. While this is in progress studies on large animals, previously begun in association with Professor T. J. Mackie of Edinburgh University, will be developed with the object of determining the relation between blood changes induced by faulty diets and immunological reactions. In these studies Mr. S. T. Harriss, the newly appointed veterinary surgeon on the staff of the Rowett Research Institute, will take a part and guidance will be available from Professor Cruickshank and Dr. John Smith on the bacteriological side and from the staff of the Animal Diseases Research Association on the veterinary side. These proposals were subsequently accepted by the Council, subject to consideration of the views of the Agricultural Departments.

In the paragraphs which follow, reference is made to certain other investigations which are under the co-ordination of the Council's Committee on Nutrition in Relation to Disease.

" Border Pining " in Sheep: Investigations in Northumberland.—In April, 1936, the Animal Diseases and Nutrition Committees of the Council considered proposals for joint investigations by Mr. W. Lyle Stewart, the Veterinary Investigation Officer at Armstrong College (now King's College), Newcastle-upon-Tyne, and his assistant Dr. A. Phyllis Ponsford, and Dr. H. H. Green and Mr. E. L. Taylor of the Veterinary Laboratory of the Ministry of Agriculture and Fisheries at Weybridge, into Northumbrian " pining " in sheep, which preliminary investigations at the College had indicated might be caused by a combination of malnutrition (possibly arising from mineral deficiencies) and parasitic infestation. The limited experimental data which had been collected did not point to lack of iron alone as the cause of Northumbrian " pine," though Scottish workers at the Moredun Institute, the Rowett Research Institute and the Macaulay Soil Research Institute have found it to be so in " pining " areas in Kirkcudbrightshire and Roxburghshire as well as in Tiree. In those areas it appears that " pine " can be prevented and cured by administering iron compounds. Again, in Northumberland heavy worm infestation is usually associated with " pining," but it was not believed that such infestation by itself could explain the course of the disease. The symptoms are a progressive emaciation associated with anaemia. Workers in New Zealand and Australia consider that cobalt is of importance in controlling " pine " in those countries.

For the purpose of the further investigations by the workers at Newcastle and Weybridge a hill-side on the farm at Trows, about 50 miles from Newcastle in the direction of the Scottish border was finally selected. On this farm " pining " was severe before the practice was adopted of giving the sheep change of pasture. The owner placed this hill-side and 200 of his sheep at the disposal of the investigators. The scheme adopted was to fence off the land into five sections, each of 45 acres, and to divide the sheep into six groups, each originally consisting of 32 sheep. Their lambs will, of course, also be in the enclosures, up to the time of sale. These groups are further divided into four sub-units of eight females of varying ages, and by selling off old ewes and lambs the population in an enclosure is kept constant, while certain individuals can, it is hoped, be retained from birth until the end of the experimental period. Group 1, though kept in fenced enclosures, is being treated as in ordinary farming practice and given brief triennial changes of pasture in the hope of preventing " pine "; group 2 consists of earmarked sheep allowed to range freely with the main flock and acts as a control to group 1; group 3 is kept in an enclosure and allowed no change of pasture; group 4 is treated as group 3, but receives a supplementary ration of heavily mineralised cake, containing a variety of minerals and also two per cent. of cod-liver oil; group 5 is treated in the same way as group 3, but receives anthelmintic treatment monthly in the form of doses of copper sulphate and nicotine; finally, group 6 receives both the supplementary mineral and vitamin ration and anthelmintic treatment, in order to ascertain whether " pining " can be controlled without moving the sheep to other pastures.

Clinical observations and worm egg counts are made at regular intervals and a count of actual worms present will be made in all sheep which die, and in a selected number of clinically healthy animals from each group killed for the purpose. Some of these will also be examined to determine whether in the skeleton there are signs of change due to mineral deficiencies. Ewes and lambs are weighed at regular intervals and blood samples are taken, and pasture samples are to be collected analysed and studied spectrographically from " pining " farms, " non-pining " farms and farms to which sheep are normally moved in the hope that " pining " will be prevented by a change of pasture.

The proposals finally submitted to the Council were framed after consideration of the views of members of the Animals Section of the Council's Committee on Helminths as well as of the Animal Diseases and Nutrition Committees. In aid of the scheme as amended the Council agreed with the Ministry of Agriculture and Fisheries that a grant not exceeding £900 should be made to Armstrong College, spread over a three year period, which was to begin in August, 1936. The total cost over the three years was estimated to be £1,890 and included the salary of Dr. Ponsford, £500 for fencing and £300 for compensation to the owner of the farm for sheep. The remaining sum, not exceeding £990, is to be found from other sources, and of that sum at least £855 is being guaranteed from the Alan, Duke of Northumberland Memorial Fund. The investigations, as explained above, are being carried out in collaboration with Dr. Green and Mr. Taylor of the Ministry's Veterinary Laboratory and they are conducted under the general co-ordination of the Council's Committee on Nutrition in Relation to Disease, of which Dr. J. Russell Greig, Director of the Moredun Institute of the Animal Diseases Research Association, who took a leading part in the investigations on " pine " in Scotland, is a member.

Investigations on the relationship between deficiency of vitamin A in pigs and susceptibility to intercurrent infections.— In the Third (Interim) Report of the Council's Committee on Swine Fever, Necrotic Enteritis and Similar Diseases of Pigs, the Council's attention was drawn to the considerable advance made by workers at the National Institute for Research in Dairying at Shinfield, near Reading, since the submission of the Committee's previous Report, in gaining knowledge concerning deficiency of vitamin A in young pigs, particularly with regard to vitamin storage in the liver and the rate of exhaustion of vitamin reserves. The survey of diseases of young pigs made by Mr. N. H. Brooksbank on behalf of the Committee on Swine Fever, etc. (p. 244) had, on the other hand, produced evidence that malnutrition in early life rendered young pigs less resistant to disease. The Committee pointed out that necrotic enteritis, the most important cause of early mortality in pigs, was erratic in its incidence and that nutritional anaemia, another important cause of early mortality, was often followed by enteritis. The Committee therefore represented that it was desirable to make an investigation with the object of discovering whether (*a*) experimental vitamin A deficiency in its earliest stage, and (*b*) experimentally induced nutritional anaemia at the same stage, do influence the susceptibility of the young pig to contract *Salmonella suipestifer* infection, which causes necrotic enteritis, by way of the alimentary tract. The Committee proposed that the work should be done in collaboration between the Veterinary

Laboratory of the Ministry of Agriculture and Fisheries at Weybridge (the Director, Dr. H. H. Green and Mr. T. M. Doyle) and the National Institute for Research in Dairying (the Director, Captain J. Golding and Dr. S. K. Kon) and that £200 should be allocated to these researches from funds at the disposal of the Council. The Council accepted this recommendation and agreed to propose to the Ministry of Agriculture and Fisheries that estimate provision should be made accordingly in the financial year 1937-8. They requested that a more detailed programme should be submitted to the Council's Committee on Nutrition in Relation to Disease.

A tentative programme was duly submitted to that Committee in November, 1936. It was proposed to maintain sows and to rear litters at Shinfield under conditions known to lead to lack of vitamin A and to the form of nutritional anaemia which can be treated by administering iron, and to send the young pigs at intervals to the Ministry's Veterinary Laboratory. For the purpose of the vitamin experiments the pigs would be sent in batches of about eight at the age of 14 weeks; one-half would have been fed on a deficient diet from the time of weaning at the age of eight weeks, and the other half would receive abundant vitamin A in concentrated form. From each batch one pig would be killed and the liver reserves would be estimated in order to provide " control " information. Approximately the same number of pigs would be sent to Weybridge in each batch for the nutritional anaemia experiments, but they would probably be sent at the age of about three weeks. The haemoglobin content of their blood would be determined. One-half would be suffering from milk anaemia; in the other half anaemia would be kept in control by the addition of iron and copper to their diet.

After arrival of the pigs at Weybridge they were to be given graduated doses of a known culture of S. *suipestifer* and to be kept under observation as long as was necessary. Attempts would probably be made later to produce infection by contact with pigs suffering from necrotic enteritis. It has, in fact, since been found that the method of infecting by feeding with the organism is not very satisfactory. When the pigs were killed, liver samples would be sent to Shinfield so that their vitamin content could be determined. It was proposed that one-half of the cost of the experiments, in addition to salaries, should be found from the normal budget of the Institutes.

The Committee on Nutrition in Relation to Disease, when they considered this programme, were informed that Golding and Kon at Shinfield and Dunlop at Cambridge had shown that many pig rations were deficient in vitamin A, but that though the incidence of disorders traceable to lack of vitamin A in pigs at the age of six months must be considerable, the condition might not be generally recognised. There would be no clinical symptoms at that age nor would the growth-rate be affected until some months after weaning, and many pigs were marketed for slaughter at about the age when the effect of lack of this vitamin would be apparent.

With regard to anaemia, there was field evidence to suggest that losses from necrotic enteritis were heaviest in pigs which had suffered from anaemia, and were consequently in a weak condition. In sty-fed pigs anaemia might continue until weaning, and scouring associated with pronounced anaemia commonly occurred at the age of two weeks. Mortality might result from anaemia or from secondary infection.

The Committee agreed that the programme should be approved and be carried out under their general co-ordination. It was arranged that the possible importance in relation to necrotic enteritis of a vitamin B2 factor should, because of the experience of Martin and Chick during the course of their experiments on that vitamin at Cambridge, be borne in mind.

In accordance with their Committee's advice, the Council recommended that a special sum of £200 should be made available towards the cost of the approved programme at the National Institute for Research in Dairying and the Veterinary Laboratory of the Ministry of Agriculture and Fisheries during the financial year 1937-8.

Research in the Department of Biochemistry, Oxford, on Dietary factors affecting normal health in poultry and pigeons.—In August, 1937, the Council offered a grant to the University of Oxford of £250 for the year beginning the 1st October in aid of the continuance and extension of research work in the Department of Biochemistry, under the direction of Professor R. A. Peters, on the dietary factors required to maintain normal health, growth and fertility in poultry and pigeons and on the nature of such pathological conditions as are of dietary origin. The grant would provide the wages of an assistant and sums for the purchase and maintenance of animals and the cost of special materials. The Council informed the University that, subject to funds being available and to their being satisfied with the progress of the work, which would be under the general co-ordination of the Council's Committee on Nutrition in Relation to Disease, they would be prepared to consider favourably applications for grants at the same rate during a further period of two years.

In making the application Professor Peters referred to the investigations on the nature and function of essential dietary factors required by the pigeon and chick which had been in progress for some years by himself and his colleagues (C. W. Carter and J. R. O'Brien) at Oxford and to parallel work in America by Hart and his colleagues, by Elvejhem and Koehn, Lepkovsky and Jukes, Pappenheimer, Dam and Schonheyder and others. At Oxford the work on pigeon nutrition, which had been aided by the Medical Research Council, arose in the course of researches on the nature and function of vitamin B1. It had been shown that deficiency of this vitamin resulted in polyneuritis, associated with a disturbance of the carbohydrate metabolism of the brain in pigeons and rats, and that in addition to vitamin B1, vitamin B3 (as confirmed independently by Williams and Waterman in America) and vitamin B5 were necessary for the normal development of the pigeon. Weight was maintained by adding to vitamin B1, and to the fat soluble factors in the daily ration, flavin, an alcoholic extract of vitamin B1 containing B5 and a liver extract containing vitamin B3. Absence of these factors was associated with sub-normal growth rate, but there was no appearance of characteristic lesions. In chicks fed on synthetic diets supplemented with crystalline vitamin B1 and flavin, growth was sub-normal and dermatitic lesions occurred. Growth was recovered and the dermatitis cured by administering extracts containing the same factors as those required by the pigeon. The American work indicated that, in addition to vitamin B1, the chick requires flavin, a factor which cures pellagra, a factor which cures paralysis and two fat-soluble factors besides vitamins A and D, namely, anti-haemorrhagic curatives of a scurvy-like group of symptoms and a factor curative of certain severe disorders of the brain.

Professor Peters desired, in particular, to develop researches bearing on the definition of the nature of vitamins B3 and B5 and the " heart-block " factor in the pigeon, and on the relation of these factors to known and unknown vitamin factors required by the chick as well as the rat. In conference with the Committee on Nutrition in Relation to Disease, Professor Peters urged the need for work on a considerably larger scale with pigeons, and also with chicks as soon as the question whether vitamin B5 was the same as vitamin B6 was settled. In the discussion of this programme it was pointed out that work of this character was not in progress at any of the Agricultural Research Institutes. While it was true that poultry might obtain the vitamin B factors necessary for normal health in whole grain, from the practical point of view economy of feeding might be improved as the result of these investigations by the partial substitution of small amounts of concentrates, while material additions might be made to more fundamental knowledge. The Council reached their decision to aid this work after consultation with the Medical Research Council and the Ministry of Agriculture and Fisheries. The Ministry referred to the lack of information regarding the relation between nutrition and health in poultry.

Metabolism of fats, with special reference to the study of experimentally produced " fatty livers " in sheep.—An investigation is being carried out by Professor Henry Dryerre and Dr. J. P. Dickson at the Royal (Dick) Veterinary College, Edinburgh, into the metabolism of fats, including separation, identification and quantitative determination of the individual lipoids in the blood and other body tissues. Special attention is being given to the study of the experimentally produced " fatty livers," and the qualitative and quantitative determination of fats in the liver, with a view to ascertaining the mode of accumulation in, and elimination from, the liver. The effects of choline, caseinogen, triethyl-β-hydroxethyl, ammonium hydroxide and various lipides in their relation to fatty livers are being tried.

Observations on rabbits are being carried out in the first instance. Later the work will be applied to ruminants, with particular application to the sheep, in which the nature, distribution and metabolism of the lipides during pregnancy, and the departures from the normal which occur in the toxaemias of pregnancy in the ewe, will be investigated.

At the conference of workers on ketosis held in January, 1937, it was felt that this research would be likely to provide a useful contribution to the study of the problem of pregnancy toxaemia in the ewe. The Department of Agriculture for Scotland were of the opinion that the investigation might eventually become useful to the stock-breeding industry. While certain disorders, such as pregnancy toxaemia in the ewe, were assumed to be associated with some dietetic disturbance manifested by an undue accumulation of fat in the liver, there was apparently no evidence which would suggest that a fatty liver is an invariable accompaniment of these disorders.

A grant of £53 in aid of this investigation during the financial year 1937-8 was made to the College on the recommendation of the Council and with the support of the Scottish Board of Research in Veterinary Science. The work is being done under the general supervision of the Council's Committee on Nutrition in Relation to Disease and in collaboration with other workers, including those at the Rowett Research Institute, Aberdeen.

Ketosis of Ruminants.—The disorder known in a fairly wide general sense as ketosis is associated with disturbance of carbohydrate and fat metabolism reflected as pronounced acetonaemia, and is most common as a pre-parturient condition in ewes and a post-parturient condition in cows. In the ewe the disorder occurs most commonly about three weeks before parturition in ewes bearing twin lambs, and is known under various names, such as " pregnancy disease " (in Australia and New Zealand), " domsiekte " (in South Africa), " in-lamb ewe disease " (in Wales) and " moss-sickness " (in Yorkshire). It is sometimes confused with a hypocalcaemic condition termed " lambing sickness " (analogous to " milk fever " of cows), into which it sometimes passes if the ewe survives to parturition, but which may occur quite independently of ketosis. Mortality may be heavy, either as a direct result of the condition or as a result of secondary pneumonia following exposure and disinclination to move. Clinically the main symptoms are lethargy, cessation of grazing, partial stupefaction and, in some cases, disturbances of vision. When lung lesions are absent, fatty liver is the most characteristic post-mortem finding. There is no reliable treatment and until the genesis of the disorder is fully understood specific preventive measures cannot be recommended. Mild cases usually clear up a few days after parturition, but mortality may be very heavy in the weeks preceding lambing.

In the cow the disorder is commonly called " puerperal dyspepsia " and " acidosis." As a pre-parturient condition it is very rare, but as a post-parturient sequel to milk fever it is common in certain breeds. Although the condition is rarely fatal and gradual recovery usually ensues over a few weeks, the milk yield falls off badly, the milk is tainted, the animal loses condition and the " sick cow " is a worry both to the owner and to the veterinary practitioner, who has no reliable therapy at his disposal. Preliminary data suggest that massive intravenous injections of glucose, preferably with insulin, may cut short an attack in the early stages, but further research on the whole disorder is badly needed.

The reasons why the disorder is epizootic in character in the pregnant ewe, but sporadic in the cow after parturition, are obscure. While the term "ketosis" can be used in a general sense to relate the condition in both animals, there is not sufficient evidence to justify the two conditions being regarded as a single pathological entity. In the case of the ewe, it may preferably be said that a number of disorders can be grouped under the general designation of pregnancy toxaemia. For the present the whole pathological picture is obscure, pointing to no more than a cycle of events which causes an upset of fat metabolism. For the highly fatal condition in ewes, with its high flock incidence, a system of prevention for the flock as a whole is needed. In the case of cows the incidence is always sporadic and therapeutic treatment of the individual is probably the practical method.

Work on this problem is being assisted at the Veterinary Laboratory of the Ministry of Agriculture and Fisheries at Weybridge, and the Royal (Dick) Veterinary College, Edinburgh. At Weybridge the normal Vote provision for Veterinary Pathology is being supplemented during the financial year 1937-8 by a sum of £100, made available on the Council's recommendation to meet the additional experimental costs of work being undertaken by Dr. H. H. Green. The overhead costs and travelling expenses of the work are found from the normal Vote provision and the sum of £100 is provided to meet exceptional payments, such as are involved in the transport of a few affected cows to Weybridge and in compensating farmers for sheep slaughtered *in situ* as material for the study of the early stages of suspected ketosis. Observations upon the conditions of occurrence of the disease are being extended by enlisting the co-operation of the Veterinary Investigation Officers in the various provinces of England and Wales, of the Inspectorate service of the Ministry of Agriculture and Fisheries and of selected veterinary practitioners. Reports and diagnostic material from these officers, each covering a different district, should indicate the general position throughout the country as a whole, in respect of pre-parturient ketosis of ewes. For the dairy cow, the main source of co-operation is the dairy practitioner who appears anxious to submit clinical reports and blood samples to Weybridge in return for biochemical diagnosis. In a few selected cases cows, which have had repeated attacks of post-parturient ketosis, are bought and sent to Weybridge for detailed study at subsequent calvings.

A second line of attack, namely, the experimental production of ketosis in small ruminants, while forming part of the programme, has not yet been developed at Weybridge owing to temporary difficulties of securing the necessary skilled laboratory assistance.

At the Royal (Dick) Veterinary College, Edinburgh, Professor G. F. Boddie, in collaboration with Professor Henry Dryerre, also of the College, and with Dr. James Stewart of the Moredun Institute of the Animal Diseases Research Association, is concentrating attention on the examination of blood and urine from pregnant and lactating cows as an aid to diagnosis of the disorder. This work was assisted by a special research grant of £90 during the financial year 1936-7 and is being continued during 1937-8 with a further grant of £115, the increase being provided to enable a larger number of blood samples to be collected. Earlier work done on the urine of apparently normal dairy cows showed that a varying degree of ketosis was present in a considerable proportion of pregnant and lactating dairy cows, and that this state became increasingly prevalent towards the end of the winter. This finding demonstrates the existence of a degree of toxaemia, which results in a state of ill-health rendering animals more susceptible to other diseases. The grant is enabling more frequent examinations to be made of the blood and urine from pregnant and lactating cows, with special reference to the changes in the amount of blood sugar and blood ketones and the relationship between blood and urinary ketones. Material from cows affected with post-parturient diseases is also being examined through the co-operation of practitioners.

The Council's Committee on Nutrition in Relation to Disease, under whose general supervision the grant-aided work in this field is being conducted, decided that the general programme would be greatly assisted by a conference of the workers concerned, especially as it became apparent that centres other than Weybridge and Edinburgh were interested in the problem. Dr. A. H. H. Fraser of the Rowett Research Institute, Aberdeen, had been making observations on pregnancy toxaemia in ewes and was anxious to develop the work in co-operation with the Moredun Institute, while workers at the National Institute for Research in Dairying, Reading, particularly the Director, Professor H. D. Kay, and Dr. W. L. Davies, were interested in the subject. Two meetings of this conference were convened in the period under review, the first in January and the second in June, 1937. These special meetings have proved of considerable value for the purpose of comparing progress and planning future work and they have defined the objectives. In the case of the condition in the cow, the need is to obtain a clearer blood picture of the elements concerned in clinically diagnosable ketosis and post-parturient dyspepsia as compared with the normal for particular herds, and to endeavour to correlate the " normal ", where it shows features diverging from the levels ordinarily found in the blood, with subsequent occurrences of acetonaemia, past-parturient dyspepsia, or milk fever. At the first conference it was agreed that the major part of the work on ketosis in specific herds should be done by the Edinburgh workers, but that supplementary observations should be made at Weybridge and Reading, the object being to obtain data regarding several different breeds. Professor Kay of the Reading Institute had pointed out that disturbance of the parathyroid, which appeared to be a feature of milk fever, would be expected to affect the level of serum phosphatase. The Institute undertook to do phosphatase determinations, which might serve to distinguish between different types of post-parturient disturbance. As regards the condition in the ewe, the discussion pointed to probable new lines of enquiry which might prove profitable. The most important aim is to reproduce the disease experimentally.

At the second meeting of the conference, Professor Boddie gave an account of the results obtained by himself, Professor Dryerre and Dr. Stewart from the analysis of 214 blood samples taken from 50 cows, belonging to four dairy herds and one beef herd, at monthly intervals from February to June, 1937. The most important finding appeared to be an occasional very high content of acetone bodies in the blood without any clinical symptoms of disease. It was decided that the results should be examined statistically in order to ascertain whether any of the correlations were significant. It was arranged that thyroxine should be administered in several cases with a view to ascertaining its suitability in the treatment of animals suffering from ketosis. Dr. Fraser of the Rowett Research Institute described experiments conducted in co-operation with the North of Scotland College of Agriculture relating to the influence of nutrition on the disorder, and the work at the Institute on pregnancy toxaemia in sheep. Mr. R. S. Roberts, the Agricultural Research Council's Research Officer for work on sheep diseases, gave an account of his survey work, with special reference to pregnancy toxaemia and allied conditions.

The Committee on Iodine Deficiency and Thyroid Disease.

The great influence of the thyroid gland on metabolism and growth and the fact that its active principle, thyroxine, contains iodine makes it desirable to investigate the extent to which this element is to be found in farm crops, and how far its occurrence in them is influenced by the amount of iodine in soil. The formation in 1932 of a Joint Committee of the Medical Research Council and the Agricultural Research Council on Iodine Deficiency and Thyroid Disease, to co-ordinate the work on this subject of interest to the two Councils, was referred to in the last Report of the Agricultural Research Council. The investigations carried out by Miss G. Mason in a laboratory specially equipped at the Rowett Research Institute for research on thyroid metabolism and iodine deficiency was supported by an annual grant of £250 from the funds at the Council's disposal during the period now under review.

In the autumn of 1936, the Committee met representatives from New Zealand to discuss the work in progress in that Dominion on iodine deficiency. Arrangements were made at that meeting for keeping the Dominion in touch with work at the Rowett Institute, and it is hoped later on to initiate parallel investigations in several countries.

The Rowett Institute is co-operating with University College Medical School and Weybridge Veterinary Laboratory in these investigations. The very difficult problem of an adequate analytical method has been solved, and so much of the investigation as is concerned with the incidence of goitre in school children has been completed and published, the somewhat unexpected result being that there is little connexion between a common occurrence of goitre and a deficiency of iodine in the soil or in plants growing in it. Work is in progress on the availability of iodine from different sources.

The Rowett Institute is still carrying on work on the influence of temperature, diet and the administration of iodine and thyroxine on the histology and iodine content of the thyroid gland.

An investigation has been started on the channels of excretion of iodine. Considerable work has been done on the normal variations in the iodine content of the gland and the correlation between this, the histology of the thyroid, and the metabolic rate of the animal.

Suggestions have been made of a connexion between radioactive substances and endemic goitre. Experiments were accordingly carried out at the Institute in which rats were given daily doses of radium emanation with a standard diet. The rats so treated were found to have a tendency towards a somewhat heavier thyroid with a lower iodine content than the similar batches on the normal diet without radium. Further work on this subject is in progress.

Pig Husbandry.

Those who are concerned with research on the many aspects of pig husbandry in the United Kingdom and with the study of the effect of breeding, nutrition and management on the conformation and quality of the carcass from the point of view of the requirements of the bacon and pork markets meet together in the Pig Husbandry Research Committee, of which Professor F. L. Engledow of the School of Agriculture, Cambridge, is Chairman. The Council is represented on this Committee by Sir Thomas Middleton and Mr. John Smith, while the attendance of representatives of the Food Investigation Board of the Department of Scientific and Industrial Research and co-operation with the Bacon Development Board have brought research on production problems into much more intimate relation, as was essential, with investigations of interest to the curer, distributor and consumer. This association of those engaged in pig research resulted in the submission to the Council of an important memorandum on the present position of investigations into pig production problems, in the undertaking of a scheme of experiments on the effect on pigs of length and mode of transit from the farm to the bacon factory, and in the establishment of a Pig Experiments Co-ordinating Committee, through which co-operative investigations at a number of centres into the comparative benefits of restricted and unrestricted feeding and of home-produced and imported carbohydrate feeds have been arranged.

Reference is made in the appropriate sections of this Report to a variety of pig husbandry investigations at the Research Institutes. There follow some notes on two experimental schemes, for which special assistance is provided from the Development Fund, at the Harper Adams and South-Eastern Agricultural Colleges.

Harper Adams College.—In November, 1936, a Sub-Committee of the Council's Animal Diseases, and Nutrition and Breeding Committees visited Harper Adams Agricultural College at Newport, Salop, and discussed the practical pig feeding experiments which were in progress there with Dr. Charles Crowther, the Principal, who is responsible himself for the direction of the work. A grant of £460 was made from the Development Fund for the purpose of the experiments in the academic year 1936-7. During the summer of 1936 a study was being made in co-operation with the Low Temperature Research Station, at Cambridge, of the Department of Scientific and Industrial Research of the effects of transport upon shrinkage in live-weight and dead weight and upon the carcass quality of bacon pigs, and arrangements had been made to test the effects of different rates of restriction of feeding at various live weights under group feeding conditions, in repetition, with certain amplifications, of experiments at the Animal Nutrition Institute, Cambridge. Dr. Crowther explained to the visiting Sub-Committee that the largest series of experiments which had been undertaken at the College had been concerned with the protein supplement to the diet of pigs and had shown that, under the conditions existing in these piggeries, where all the pigs had some access to grass, as good results were achieved with vegetable proteins as with fish meal, if a mineral supplement were added. The feeding of protein in large quantities did not result in better growth rate nor in producing a greater proportion of lean to fat in the carcass. These findings confirmed those of Woodman at Cambridge. Referring to general results over the last five years at the Harper Adams College, Dr. Crowther stated that the average production of pigs was twelve to the litter, or which nine were weaned at eight weeks and eight reached the marketing stage. In ten years it had been possible to reduce the cost of production by 1s. 6d. per cwt., and advice on rationing had been given to a large number of farmers. As the pigs used in these experiments had access to grass every day, an iron supplement was not found to be necessary; the only essential minerals were lime and salt. During the first two years of the experiments, when there was not enough pasture, some anaemia occurred among the pigs.

South-Eastern Agricultural College, Wye.—In November, 1935, a Sub-Committee of the Animal Diseases and Nutrition Committees of the Council, acting on a request made by the Development Commissioners, examined proposals made by the South-Eastern Agricultural College, Wye, for the more intensive study of problems of pig nutrition, which involved the freeing of Mr. V. C. Fishwick from his routine lecturing duties, so that he might devote practically the whole of his time to pig husbandry investigations. These proposals were recommended for approval by the Sub-Committee and were subsequently carried into effect, the grant from the Development Fund being increased from £240 in the academic year 1934-5 (exclusive of any additional grant required for the restoration of salary " cuts ") to £740 in 1935-6.

Members of the Council's Sub-Committee visited Wye on the 20th July, 1936, when they had the opportunity both of hearing from Mr. Fishwick a summary of his experiments, which starting in 1929 had been concerned mainly with problems of rearing, and of seeing the experimental animals and piggeries. From the first experiments on indoor versus out-door systems of management it was observed that the mortality amongst small pigs reared indoors was very high. They suffered severely from scour and absence of appetite between the ages of three and six weeks. Some breeders thought scour to be due to overfeeding, but there was evidence of malnutrition when 10 lb. per head per day of a ration containing 5 per cent. fish meal was given to the sow, and improved results, though still inferior to those obtained out of doors, were obtained when the ration was increased to 16 lb. with 10 per cent. fish meal and a mineral supplement. In the winter of 1933-4 two rations were tested, containing, respectively, 10 per cent. fish meal and 2½ per cent. blood meal, and 7½ per cent. fish meal and 5 per cent. dried milk. The number of pigs reared per litter on these diets was 7·6, the average litter weight at eight weeks was 207 lb. and the average pig weight at that age 27 lb. In the late spring of 1934 an outbreak of necrotic enteritis destroyed 22 per cent. of the young pigs aged from three weeks upwards. By confining the food of the little pigs to cereal meals only, the mortality was checked, the growth rate was raised by 30 per cent. and the litter average was increased by 8 per cent. The disease re-appeared in the late spring of 1935 amongst pigs kept after weaning out of doors on a ration of 10 per cent. fish containing meal, in addition to young grass known to have a high protein content. The loss of pigs was 21½ per cent.

The total ration of the nursing sow was next reduced to 12 lb., and in the winter of 1935-6 the sucking pigs were given a mixture of barley water and Parish's food. The average number of pigs reared in the barley-water-iron group rose to 9·4, the average litter weight was 264 lb. and the average weight per pig was 26·4 lb. The mortality during the nursing period was 2 per cent. and after weaning 12 per cent. In the control group 8·1 pigs were raised, the average litter weight was 189 lb. and the average pig weight was 23·8 lb. The pre-weaning mortality was 11 per cent. and the post-weaning mortality 20 per cent.

In the late spring and summer of 1936, when the modified ration for sows was used and most of the piglings received the barley-water-iron mixture, there was no case of necrotic enteritis. The average number of pigs reared in the herd rose to 9·3, the average litter weight was 257 lb. and the average pig weight was 27 lb. Mortality fell to 2 per cent. before weaning and 5 per cent. after weaning.

Mr. Fishwick drew the conclusion from these experiments and from earlier ones in feeding liver that nutritional anaemia was at the root of the troubles experienced. He considered that the falling off in late spring and early summer in the losses among pigs receiving barley water and iron suggested a climatic factor and he urged that the effect of giving better protection in the pens after weaning should be tested. For this purpose an additional house was subsequently provided, one-half of the cost being found by a grant from the Development Fund. While anaemia was checked by iron in the ration, it was believed that malnutrition was the primary cause of the disorder and the addition of spray-dried separated milk in liquid form was tried with encouraging results. Mr. Fishwick's observations coincide with those of Dr. Donald at the Institute of Animal Genetics and with earlier German observations in regard to the uneven quantities of milk from different teats of the sow.

In the experiments of 1936-7 the feeding of barley water and dried milk reduced mortality up to the age of twelve weeks by a further 50 per cent. and increased the average weight per pig at twelve weeks by about 30 per cent. It was, however, considered to be desirable to make a controlled experiment to ascertain the value of succulent forage in the ration of sows so as to reduce malnutrition during pregnancy and nursing; malnutrition of the sow may, it is believed, be the underlying cause of some of the weaknesses in piglings.

Experiments are also being made in co-operation with Dr. John Hammond of the Animal Nutrition Institute, Cambridge, in crossing Large White and Saddleback pigs, and observations are in progress on variations in litters in the thickness of back fat and flank, on the possible correlation between growth prior to weaning and the thickness of back fat and flank in bacon pigs, on the capacity of gilts to rear their pigs, and (at the cost of the Brewers' Institute) on the value of brewers' grains in the ration of growing and fattening pigs.

Experiments in Poultry Husbandry.

Under the National Poultry Institute scheme in its present form poultry investigations are assigned to several institutions. At the Harper Adams Agricultural College, Newport, Salop, is the chief centre for education and for the study of the more immediate and practical difficulties of the industry. This centre is the National Institute of Poultry Husbandry. Fundamental problems in nutrition are allocated to a section of the Animal Nutrition Institute at Cambridge, and problems of disease to the Veterinary Laboratory of the Ministry of Agriculture and Fisheries, while at the School of Agriculture, Reaseheath, Cheshire, investigations are undertaken bearing on the breeding of poultry for egg production and at the South-Eastern Agricultural College, Wye, on those affecting the breeding and rearing of table poultry.

The Council have in the past two years reviewed certain experiments at the Harper Adams and Wye Colleges.

Harper Adams College.—The Council are not directly concerned with advising on the educational grants to the National Institute of Poultry Husbandry which cover the cost of many of the practical investigations in progress, but in November, 1936, a Sub-Committee of the Council's Animal Diseases, Nutrition and Breeding Committees visited the College to review certain investigations originally financed by grants from the Empire Marketing Fund and subsequently, on the Council's advice, by grant-aid from the Development Fund, which in 1936-7 amounted to £1,300. These grants had made possible an extension of the work from the study of egg production problems to the investigation of table poultry, water fowl and marketing problems. Amongst the investigations made were those concerned with the new methods of brooding, systems of rearing table chickens, methods of fattening and finishing, egg faults and the measurement of egg quality, the storage of table chickens, methods of managing and feeding waterfowl for egg and table production, and the incubation, brooding, rearing and fattening of turkeys. The progress of the work was discussed by the visiting Sub-Committee with Dr. Charles Crowther, the Principal of the College, and Mr. A. J. Macdonald, the Deputy Director of the Institute. During the course of the discussion stress was laid on the high rate of mortality in poultry flocks, which has since been brought prominently before the public by the Report of the Poultry Technical Committee. At Harper Adams College the heavy rate of mortality and disease in the experimental plant had compelled concentration on table poultry production, and the average mortality in the laying trials had risen from 5 per cent. to over 20 per cent. in spite of considerable improvements in feeding. In the table poultry experiments attention was being given to the possibility of replacing maize meal by weatings and the most economical use of milk. The earlier results secured in the rearing of chickens were being applied to table ducks. As was the case with chickens, a simple protein supplement proved as satisfactory as a mixed supplement. The effect of reducing protein in the rations of laying ducks was being tested. A ration of cereals plus salt was found to give as good a result as one of cereals plus a mixed supplement. In regard to turkeys, the economics of production in the Black Norfolk and Mammoth Bronze breeds and the possibility of introducing the smaller Canadian turkey were being examined.

The programme for the academic year 1937-8, which came before the Council's Estimates Committee, covered experiments designed to discover the growth rate of chickens reared under different conditions and receiving varying levels of protein in the ration; a comparison between feeding birds which are being fattened in runs and in the fattening sheds with pellets and with wet mash; investigations on losses which occur under different methods of dressing and cooking fattened table poultry; comparative tests of fattening table ducks indoors and in runs; experiments in feeding laying ducks with a ration of cereals plus minerals, as compared with a ration of cereals plus protein and minerals; investigations on different methods of managing turkeys and their effect, in particular, on weight and quality of carcass and control of mortality from Blackhead Disease; and observations on the rate of growth, etc., of the new Charlevoix breed of turkeys and on the influence of feeding and management on yolk colour, condition of white and flavour of turkey eggs.

South-Eastern Agricultural College, Wye.—The experiments in the breeding and rearing of table poultry were examined by a Sub-Committee of the Animal Diseases, Nutrition and Breeding Committees of the Council in November, 1935. One experiment then in progress, which was nearing an end, was designed to compare the results of battery brooder treatment with those achieved by older methods, using for this purpose birds of the Light Sussex and Rhode Island cross. The experiments were intended to give guidance to small rearers who cannot employ a crammer. Birds reared in Sussex arks seemed to be better feathered and to show less signs of feather picking and cannibalism than those in the battery, but, on the other hand, among the battery reared birds losses from Coccidiosis were very small, whereas very heavy losses, even at the age of five days, were experienced in the old brooder houses. The Sub-Committee considered that the experiment had been well designed and was being admirably conducted. A further experiment was intended to investigate the possibility of producing a small chicken, which can be marketed for 2s. 6d., by crosses between Old English Game birds, Scotch Dumpies, Faverolle, Light Sussex, La Bresse and White Wyandottes. These crosses, the Sub-Committee noted, had failed. Where Old English Game cockerels were used few eggs were laid, and less than half the eggs were hatched. Growth, too, was much slower than that in commercial breeds and crosses. Nevertheless, as many of the crosses had produced birds which at the age of fifteen weeks, though they had not received a special diet, were superior to imported birds, the Sub-Committee recommended that the experiments should be continued, using pure Cambars, and crosses between English Pheasant and Rhode Island Reds and between Bantam Dorkings and Light Sussex. The Sub-Committee emphasized the desirability of arranging for the services of a geneticist being available when experiments of this character were to be undertaken.

Under a re-arrangement of the programme made in 1934, one-third of the special plant at the College was to be devoted to experiments in producing the quickly maturing type of small table bird, the remainder of the plant being used for investigations on the economics of production of the type of table bird known as the country chicken, which is chiefly in demand in the home market. The Development Commissioners desired that every effort should be made to restrict expenditure at this centre to £800 per annum, and it was therefore arranged that as from the 1st October, 1937, no birds should be marketed at as early an age as 14 to 15 weeks. Receipts from the sale of these young birds had proved to be uneconomic. The experiments were to be confined under the revised programme to intensive methods of management so as to rest the stale land, on which extensive methods had been continued for a number of years, with the result that birds kept on that land were inferior. The general scale of the experiments was also reduced.

School of Agriculture, Reaseheath, Cheshire.—In 1933 a fresh programme of work at the Northern Poultry Breeding Station at Reaseheath was adopted after full consultation between members of the Northern Sub-Committee and a Sub-Committee of the Animal Diseases, Animal Nutrition and Breeding Committees of the Council. The main line of work pursued has been a comparative test of the respective merits of the first cross and of pure breeding in regard to such factors as fecundity, hatchability, rearability, rate of growth, time of reaching maturity and egg quality. Subsidiary investigations are concerned with the question whether the very high degree of infertility recorded in White Wyandottes is inherited, and with an attempt to produce a strain of poultry of one of the commercial breeds which will withstand continuous inbreeding. These experiments have been continued since the approval of the programme; the data are being analysed and it is proposed that when the experiments end, in 1938, a full report shall be prepared. The net cost in the financial year 1937 was estimated to be £745.

ANIMAL BREEDING.

Institute of Animal Genetics, University of Edinburgh.

The work of the Institute of Animal Genetics, Edinburgh, of which Professor F. A. E. Crew is Director, was re-organised as the result of consultations which took place early in 1933 with Professor Crew, who submitted proposals to a special Sub-Committee of the Council. Re-organisation and some reduction in staff was made necessary owing to financial difficulties arising from a fall in the value of shares provided by way of private endowment, but, apart from purely financial considerations, the view of the Council's Animal Diseases, Nutrition and Breeding Committees was that in so difficult and specialised a field of research as animal genetics it was desirable that the permanent nucleus staff should be small, but highly trained and well qualified. Since the consultations with Professor Crew took place, Mr. W. C. Miller, who was responsible for work on the biology of the fleece and for other researches on sheep, has left the Institute on appointment to a Chair in the Royal Veterinary College, London.

In June, 1937, when the Institute was again visited by a Sub-Committee of the Council, whose final review and recommendations had not been presented at the end of the period now under report, there were four sections of the Institute: General Genetics under the Director, Physiological Genetics under Dr. A. W. Greenwood, Livestock Genetics (with the experimental farm at Shothead, near Balerno) under Mr. A. D. Buchanan Smith and Cytology under Dr. P. Ch. Koller. Rabbit breeding research is also carried on in association with the Institute under Dr. J. N. Pickard, but it is financed by means of a separate grant and by small contributions from the rabbit breeding industry, which is indebted to Dr. Pickard for valuable advice and assistance in regard to many of its problems. Under the scheme for re-arranging the Institute's work it was also intended to establish a statistical section. It has not yet been possible to do so, but the Institute in common with certain other State-aided research organisations in Edinburgh is able to call upon the services of Dr. A. C. Aitken, Reader in Statistics in the University, for guidance in the planning of experiments and the interpretation of results. The Institute forms part of the University Department of Animal Breeding and certain members of the staff have also teaching responsibilities as lecturers in the University. Post-graduate workers from many countries are attached to the Department.

As its name implies, the section of General Genetics is concerned with the advancement of fundamental knowledge essential for the elucidation of the problems of heredity and sex and reproductive physiology affecting domesticated farm animals. Work is in progress with *Drosophila,* budgerigars and mice and other suitable laboratory material. In the section of Physiological Genetics under Dr. A. W. Greenwood, an exceedingly valuable breeding stock of poultry of some 120 adult birds for experimental use is maintained and a mass of useful data regarding them is available for study. Since 1933 the Medical Research Council has made annual grants, in addition to a grant for equipment, to secure that a stock of poultry is available to workers studying the sexual hormones, and the British Empire Cancer Campaign has similarly, since 1935, provided funds in support of a scheme for distributing disease free stock to their investigators.

Experiments in selection and breeding in relation to large and small egg production, persistency of egg production and absence of moult are in progress and a stock of dwarf hens is being bred as a preliminary to investigations on the inheritance of body size. The physiological researches which are being pursued are concerned with type, number and regional distribution of succeeding feather generations; the effect of experimental interference with the endocrine system from hatching to maturity in relation to the moult, and studies on the fertilising power of sperm. The variation in the rate of growth of chickens throughout the year is being studied, and, in association with workers under the Medical Research Council, the special stock of birds maintained by grants from that Council is being used for research on the prostate gland, adrenal virilism and the nature of the sex hormones. Dr. Greenwood's researches are at present hampered by lack of accommodation and of adequate statistical assistance for the examination of his collected data. The poultry stocks in his department are unique and have afforded material of the greatest value in connection with the fowl paralysis experiments now being conducted at the Rowett Research Institute under the general coordination of the Council.

In the section of Livestock Genetics under Mr. A. D. Buchanan Smith, a long term investigation on the chief factors influencing the inheritance of milk yield or quality is occupying chief attention, the object being to ascertain whether any of these factors are sex-linked. The method adopted is crossing to uniform stock. Crosses have been made between Shorthorn beef bulls (low milk yielding strain) and dairy cows (high yielding) and between dairy bulls and beef cows of the same breed. The sons born as the result of these crosses are being mated to Ayrshire cows of uniform breeding, so as to assess the relative importance in regard to the transmission of milk yield and quality of the sire and dam. The first of the daughters produced by these matings are now coming into milk. One-third of the experimental programme is accomplished, but it will take another ten years to complete it. The Institute is fortunate in having, through the generosity of the owners of the adjoining farm of Cockburn, some 250 cattle at their disposal for the experiments. At Cockburn the cows which are being mated to three different bulls are drawn from six groups, sired by six different bulls. The half-sisters of these foundation groups of cows at Cockburn by the same bulls are distributed among six different farms in Scotland, and it is hoped by comparing the milk records on these farms with the records at Cockburn to reach a definite conclusion regarding the accuracy and practical value of the Progeny Test as a means for improving dairy cattle.

The Sub-Committee which visited the Institute and the farms of Shothead and Cockburn felt it to be desirable to place their views regarding immediate financial requirements before the Estimates Committee of the Council for consideration in connection with the Institute's budget for the financial year 1938-9. They were of opinion that though no conclusion could yet be reached as to the value of the cattle experiments, they were being well and economically conducted, that their value might be prejudiced owing to shortage of funds for their maintenance, and that it was essential that they should be supported on a more adequate scale.

The Sub-Committee were also impressed by the value of the pig work at Shothead, for which Dr. H. P. Donald is responsible under Mr. Buchanan Smith's direction, and they expressed the hope that funds might be found to carry into effect the wider scheme of work outlined in a memorandum submitted to them. During the past five years it had been necessary for financial reasons to manage the herd of large white pigs as a commercial unit; nevertheless, observations of considerable importance had been recorded. These indicated that under the management system adopted the month of farrowing exercised little influence on the rate or economy of live weight increase, which was affected, probably through overcrowding, when the number of pigs in a pen was greater than ten; that rate of live weight increase could be correlated with economy of gain, but that weight at weaning was a very uncertain guide as to future rate of weight increase; that the percentage of pigs weaned decreased as the size of litter increased, and that four pigs selected at random, or from pigs of an average weight at weaning, can be regarded as a reliable sample of the litter in measuring live weight gain. The economy of live weight gain in the progeny of different boars was being analysed and the causes of variation in young pigs before weaning, a subject to which attention is also being given at the South-Eastern Agricultural College, Wye, were being studied, both by means of the measurement of the milking capacity of the sow and by changing over parts of a litter from one sow to another.

It was proposed, assuming that funds were available, to divide the herd into two parts, maintaining one part generally as in the past and regarding these pigs as controls, and using the other part for experiments in in-breeding designed to throw light on the inheritance of such qualities as length and conformation in relation to meat quality, economy of live weight gain and texture of fat. With regard to economy of live weight gain, it may be noted that variations of 100 per cent. have been observed in food consumption as determined by the average consumption of litters, and that while the average consumption of a pig for each pound of live weight gain is estimated to be 4·2 lb. of meal, the average for several Shothead litters is less than 3 lb. and of some is 2·5 lb. With regard to the pre-weaning life, it is hoped that by interchanging parts of litters the differences in milk production of the sow will be more readily assessed through the reduction of the influence of genetic constitution of the litter. The ultimate aim of all these experiments would be to test the value of hybrid vigour, by first analysing and then bringing together desirable characters. If these experiments were to be carried out as planned, it would be necessary to double the pig plant at Shothead.

In the section of Cytology, Dr. P. Ch. Koller with the assistance of post-graduate workers is studying chromosome movement in widely different organisms and is making a cytological and genetical investigation into hybrid sterility. He is also undertaking research into methods of species differentiation and is making a cytological survey of the domesticated animals.

Research on rabbit breeding, for which Dr. J. N. Pickard is responsible, is carried on in very close association with breeders through the British Rabbit Council, who are also providing some financial assistance for the work. The problems arising from the production of both Angora wool and pelts are receiving attention. For Angoras the value of supplemental rations of cod liver oil for wool production has been demonstrated, and it has been shown that furnishings are inherited as a dominant factor and give an indication of high wool production. As regards pelt production, stocks of Rex rabbits with fine coats, free from diseases affecting some of the stocks originally imported, have been selectively bred, the cause of sable coloration has been elucidated and the inheritance of unduly prolonged moulting and of different types of fur is being investigated. Observations have been kept for nine years bearing on litter size, sex ratio and the duration of pregnancy and on infertility. New varieties of value to the fur industry have been produced. Dr. Pickard urged the need for further accommodation and stock in connection with his work.

Small Animal Breeding Institute, Cambridge.

The work of this Institute, which is under the direction of the Balfour Professor of Genetics, Professor R. C. Punnett, has not been reviewed by any Committee of the Council during the period now under report. During the academic year 1936-7 breeding experiments were to be continued on the inheritance of " cream " plumage in poultry and the genetical constitution of " moch silver " birds; on mutual linkage between various sex-linked characters as part of the analysis of the sex-chromosomes, and on the formation of a new breed of poultry, exhibiting auto-sexlinkage similar to that which exists in the Cambar breed produced in the Institute. It was hoped finally to establish the " Dark Campbell " breed of ducks as a breed which could be used for sex-linkage in this species, and to continue experiments on the coat colour of rabbits, with the special object of gaining further knowledge regarding the various kinds of yellow fur in this animal.

Animal Nutrition Institute, Cambridge.

The Physiology Department of the Institute is investigating a variety of problems concerned with reproduction, including the causes of sterility in farm animals, the quality of carcases as meat, and the influence of heredity and management on the quality.

The work on reproduction has included an investigation, not yet completed, on the causes of sterility, whether they be due to such physiological causes as the failure of the *corpus luteum* to rupture or to infections of the female genital tract, or to the period in the oestrus at which insemination takes place or to purely mechanical causes.

This work is being carried out on horses, cattle, sheep and pigs; rabbits are used as a laboratory animal in studies of some fundamental problems.

The Department maintains a herd of inbred pigs now in their sixth generation. These animals show no evidence of decreased fertility or vigour, and have developed no defective characters. In consequence of this close inbreeding they have become very uniform in character and thus provide admirable material for all inquiries into the effect of different methods of management on carcase quality. They are being used for this purpose, the experiments so far carried out having shown that very considerable differences in the proportion of fat and lean at bacon weight may be produced by altering the feeding level at different ages.

The work on meat has been directed to the establishment of standard methods of measuring carcases so as to provide a method of judging quality independent of the personal experience of the judge, which would be capable of applications in every country.

A large part of the Department's activities have been devoted to a study of artificial insemination. The mechanical difficulties of the process have been practically solved, and it is now possible to collect the semen of any farm animal and to bring about the fertilisation of a female with considerable certainty.

It is, however, essential if the process is to prove of real value, to develop methods whereby semen can be kept, alive and active and capable of fertilisation, for a considerable period of time. The greater part of the work on this subject has had this object and, although it has been so far successful that cows have been successfully brought into calf with semen transmitted from Holland, much work on the fundamental questions involved in the preservation of semen still remains.

Microscopical examination of semen collected artificially has shown that different bulls differ very greatly in the number of active spermatozoa they produce, and the technique will clearly be of value in investigation of cases of male sterility or poor fertility.

Shortly after the close of the period covered by this Report, a Sub-Committee appointed by the Council visited the Institute and reviewed the work on artificial insemination.

The Poultry Genetics Department has been concerned with the improvement of the Cambar breed, which now has reached a laying rate of 196 eggs in the season for the best twenty birds. Stocks of this breed have been distributed to various institutes and breeders. Auto-sex-linking Barred Brown Leghorns, Barred Barnevelders and Buff Orpingtons have been bred and will shortly be available for distribution.

One very interesting investigation has been carried out on the available data of chick and adult mortality. It shows that the mortality of the progeny of pullets which survived to 18 months old was no higher than that of the progeny of hens or older birds, but that pullets which died before reaching 18 months old left behind progeny with an excessive death rate. The figures did not indicate that the longevity of the cock had any influence on the mortality of his offspring.

Bureau of Animal Population, Oxford.

In the Council's last Report it was recorded that the Council had expressed to the University of Oxford the hope that funds could be secured to endow on a permanent basis the Bureau of Animal Population, of which Mr. Charles Elton of the Department of Zoology and Comparative Anatomy is Director, and that the University had informed the Council that they desired to make the status of the Bureau more permanent, if its success on an experimental footing continued. It was explained that the newly appointed Professor of Pathology, Professor H. Florey, had agreed to co-operate with the Bureau in studying the causes of certain epidemic diseases among wild mammals and the relation of these diseases to periodic fluctuations in their numbers. The Council had consequently made a grant of £180 in aid of the general work of the Bureau for the year beginning on the 1st October, 1935, and a further grant not exceeding £500 towards the cost of an isolation laboratory.

The Bureau was started in Oxford University in 1932, as an experiment, to study the scientific principles affecting wild animal populations. Much of its work, although directed along the lines of pure research and the evolution of various new methods of counting animals and estimating population trends and the causes of population control, has been focussed on species of economic interest. These species include the field vole (*Microtus agrestis*), the grey squirrel (*Squirus carolinensis*), the musk rat (*Ondatra zibethica*), the mole (*Talpa europea*), the partridge (*Perdix perdix*), and also several North American fur-bearing animals.

Owing to the practical and fairly immediate interest of this research it was possible for several years to finance it almost entirely from short-term grants from Government sources, from the ammunition industry, and from various bodies interested in wild animals conservation. The Royal Society also made an important contribution towards the research on voles, on account of its general ecological bearing. In 1935, however, it became plain that such long-term research could not indefinitely be kept alive solely by short-term grants, and after investigation Oxford University in co-operation with Corpus Christi College and the Agricultural Research Council, arranged that the central costs of the Bureau (including the salaries of the Director and Secretary), should be guaranteed for a period of five years, in order that research could be continuously planned and directed.

The University had informed the Agricultural Research Council that the Hebdomadal Council were considering whether they could recommend Congregation to provide a sum of £500 a year for five years, if the balance of the necessary minimum amount were forthcoming from other sources for the support of Mr. Elton's work, which they believed might either give a new impetus to Zoology or might be found to be of importance mainly in connection with the study of epidemiology. Whatever the developments of the work of the Bureau might be, the opinion of the Hebdomadal Council was that it would be very unfortunate if its progress were retarded. It was estimated that £1,200 per annum was the minimum sum required. If such a sum could be found the University were prepared to give Mr. Elton some recognised status. In addition to the sum needed for maintenance a further amount of £500 was necessary for completing the Isolation Laboratory, and a sum of £2,000 was required to provide a new Animal Breeding building, for which the University would give a site adjoining the Pathological Laboratory. Corpus Christi College subsequently elected Mr. Elton a Senior Research Fellow on condition that the balance (£400) of the sum of £1,200 for maintenance of the Bureau were found from elsewhere.

In consideration of the value of the Bureau's work as a whole in relation both to animal pathology and ecology, the Agricultural Research Council, after consultation with the Ministry of Agriculture and Fisheries, informed the University that, subject to funds being made available by Parliament and to their being satisfied that the other contributions necessary to meet the irreducible expenditure of the Bureau during the five-year period would be forthcoming, they would be prepared to make block grants of £300 in the first year and £200 in each of the subsequent four years during the period beginning on the 1st October, 1936, towards the general maintenance of the Bureau. The Council were later informed that the Decree allocating the sum of £570 per annum to the Bureau, being the average annual amount required to complete the sum of £1,140, which a Committee of the Hebdomadal Council on further review considered to be necessary to maintain the essential work of the Bureau, had been passed by Congregation on the 9th June.

This guarantee by the University, Corpus Christi College and the Agricultural Research Council immediately resulted in other organisations contributing various grants for research in the Bureau, with the result that the total expenditure on all its activities during the University's financial year, August, 1936 to July, 1937, was slightly over £3,700, of which slightly over £2,400 was granted through the University Chest, the rest being in the form of personal grants. In particular the Medical Research Council contributed towards a special scheme of work on the pathology of voles, the Forestry Commission towards the field work on vole populations, Imperial Chemical Industries and certain private estate owners towards research on game, and the Carnegie Institution of Washington, the Hudson's Bay Company, and the Department of Scientific and Industrial Research, towards the study of fluctuations in North American fur-bearing animals.

With a staff of seven research workers (including the Director and some part-time workers), a secretary and two assistants, and with the help of several research workers who have been working in collaboration, the Bureau provides an efficient small unit for the study of various phases of the problem of animal populations. These phases are as follows: field census and other ecological observations, by which density, movements and fluctuations are measured; pathological examination in the laboratory; the breeding of certain species (mainly the vole) for experimental work and the accumulation of vital statistics; field and laboratory observations on the potential rate of reproduction; and mathematical techniques for the analysis of all these data. By these means a dynamic picture of the population in terms of numbers, potential rates of increase and the rates and causes of mortality at different ages is constructed.

Among the more interesting developments during this period recorded in the Annual Report of the Bureau for 1936-7 may be mentioned the discovery of a widespread disease in wild vole populations, caused by an organism closely related to that responsible for tuberculosis in mammals, and of the fact that for laboratory use voles can be inoculated successfully with human and bovine tuberculosis; the devising of methods of trapping voles alive and marking them with rings for the purpose of observing density and changes of the population and the range of its movements within an area; a survey of parasites of British voles, which showed that the sheep tick (*Ixodes ricinus*) is hardly ever found on them; an investigation of the food of partridges and the initiation with the help of the Institute of Agricultural Parasitology of an inquiry into the possible causes of the heavy mortality among partridges, especially in East Anglia, in the spring of 1937; and a new study of the abundance of Arctic foxes and other species in Arctic Canada and Labrador.

The Bureau contemplates continuing the study of the problems upon which it is at present engaged, with certain extensions, which may be mentioned. The discovery of vole " tuberculosis " has made it desirable for the breeding research on voles to be extended in order to find the best methods of producing them in the laboratory for experimental purposes. The rabbit problem is also to be the object of a three-year investigation, from which it is hoped to discover techniques of estimating rabbit densities, measuring fluctuations, finding their causes and recording the range of movement. A survey of game resources is also planned, in which the shooting records of various species will be collated and mapped for the whole country, in order to show the distribution of various important species, which are subject to fluctuations.

The Bureau has made considerable progress in building up a library of the literature on animal populations and on population theory, and has a large collection of reprints and reports, as well as acting as a place of deposit for unpublished material, such as the detailed results of various enquiries. In this way the Bureau is able to a considerable extent to act as a clearing house for the growing volume of literature dealing with a host of population problems. Although the Bureau's own research is primarily centred on mammals and game birds it has been found that the methods evolved in the study of other groups, such as marine fish, insects and man, are of equal importance, and form a common pool of ideas, upon which to draw.

VII.—ANIMAL DISEASES

When the Agricultural Research Council first surveyed the the research needs of the country in the fields of agriculture they decided that the most urgent subject of enquiry from the point of view of the British farmer was that of animal diseases. Recent developments which have aimed at an increase in the live stock population have intensified the risk of the spread of certain diseases. The safeguarding of the health of farm animals is more important than it has ever been, and the establishment of the State Veterinary Service now in process of formation is the most prominent of the many indications of the increasing regard which is being given by the Government to this aspect of stock forming.

The Council continue to devote a large proportion of the funds at their disposal to the furtherance of research on animal diseases; full details of the grants made for this purpose are shown in Appendix II. In many directions these diseases are the subject of intensive study in the research institutes. The want of trained staff rather than the want of funds has been the limiting factor to more rapid progress on a wide front. The whole subject of veterinary education, with which is bound up the recruitment of capable research workers in animal pathology, is under the consideration of an inter-Departmental Committee. The recommendations of this Committee should point the way to the best utilisation of existing facilities and show where improvement is still required. But already much has been done to effect improvements where they were most urgently needed, and the past two years have seen remarkable developments towards the provision of better veterinary teaching and the closer linkage of teaching with research.

VETERINARY EDUCATION AND RESEARCH.

The Council have given much consideration during the past two years to the needs in staff and buildings of the Research Institute of the Animal Diseases Research Association at Moredun on the outskirts of Edinburgh. In their first Report on the proposals of the Department of Agriculture for Scotland for the development of research in animal pathology in Scotland, presented to the Committee of the Privy Council in February, 1935, the relations between the Royal (Dick) Veterinary College and the Moredun Research Institute were discussed. To meet the Council's desire for active co-operation between the two institutions a Scottish Board of Research in Veterinary Science was formed, one of the main objects of which was to encourage a close relationship between veterinary education and research. This Board is responsible ultimately to the Department of Agriculture for Scotland and to the Agricultural Research Council.

In a second Report on the proposals of the Scottish Department for the development of research in this field, presented to the Committee of the Privy Council in December, 1936, the steps taken to implement the recommendations contained in the first Report regarding the extension of the Royal (Dick) College buildings and the gradual strengthening of the College staff were described. Plans have been prepared for considerable expansion of accommodation, both classroom and laboratory, and a grant of £20,000 on the £ for £ principle has been offered from the Development Fund for the extension and improvement of the College buildings; the first section of the extension scheme is in progress. Provision has also been, or is being made for facilitating the research work of the College staff. The Report also outlined the measures taken by the Scottish Board of Research in Veterinary Science to secure the co-ordination of biochemical research at the Moredun Institute and the College, and made recommendations for the provision of additional staff and buildings at Moredun to meet the need for extended biochemical and bacteriological work and the continued growth in the Institute's activities. These recommendations have been accepted and both staff and buildings are in process of expansion.

The new Buildings of the Royal Veterinary College in London were recently completed and opened by Their Majesties. The Agricultural Research Council have taken a deep interest in this project, especially in the provision which it has made for the adequate combination of education and research in well-equipped laboratories. Much has been done in the staffing of the teaching departments to allow of opportunities for research, but the full achievement of this objective will necessarily be a gradual process. More effective co-operation has been established between the Research Institute in Animal Pathology and the College by combining the work of the Department of Pathology with the work of the Institute. The staff of the Institute are also the staff of the Pathological Department of the College, the cost of their salaries being shared between the two institutions.

Representations continue to be made to the Council regarding the difficulties encountered in staffing veterinary research institutes and on what appear to be serious disabilities under which the junior members of the research staffs in these institutes labour. Salaries and prospects of research workers are represented as comparing unfavourably with those of practitioners or members of County staffs. Recruitment of first-class young men for research is hampered by a still persistent but now very stupid failure to recognise the proper status of the profession. Within the institutes overmuch time is sometimes required to be given to routine work, such as the preparation of vaccines, diagnostic tests and the setting out of material for post-mortems. The development of initiative and experience in original research is hampered by this and other obstacles. Even when the salary position (now under review) is put right, there will still be much to do before the best type of scientific assistance can be secured for the very important work of the research institutes in animal diseases. As a step towards this, the Treasury have approved a recommendation of the Council that a limited number of scholarships should be given to enable promising science graduates to obtain a veterinary qualification; the first of these was allotted in 1936. The establishment, as a result of consultations initiated by the Council and carried to an advanced stage by the Ministry of Agriculture and Fisheries, the University, and the Royal College of Veterinary Surgeons, of a course at Cambridge leading to both a veterinary qualification and to a University Diploma is under consideration and should, when put into effect, also attract suitable and highly qualified recruits to the research service.

SPECIAL RESEARCHES.

In their continued survey of animal diseases the Council have found that both in pigs and in poultry there is a high death rate from causes which appear to be complex. In pigs, excluding the deaths from the major infective diseases, the most serious losses occur in the litters, and the problem of their reduction has certain points of similarity to the problem of the reduction of infantile mortality in human beings. In poultry there has been a coincident spread of a serious disease, fowl paralysis, and an increase in the death rate, most marked in the laying breeds, but it is not possible to say that there is any direct connection between the two. An outbreak of fowl paralysis on the land of the Rowett Research Institute provided a favourable opportunity for further study of the disease on a large scale under the general oversight of the Council's Committee on Fowl Paralysis and Coccidiosis, and special funds were provided on the Council's recommendation for the purpose of intensive experiments. In the laying trials, in which some 25,000 birds are now annually under test, the average death rate, which ten years ago rarely exceeded 5 per cent., is now nearly 18 per cent. Much of this mortality can only be described as apparently due to a lack of constitutional vigour, but the factors really responsible have so far defied analysis. In both these branches of the live stock industry there is need for research, the existing facilities for which are far from commensurate with the importance of the interests involved.

Contagious abortion remains one of the most serious of the diseases to which cattle are liable. Intensive work on its prevention is in progress under the co-ordination of the Council's Committee on *Brucella abortus*, and is rapidly reaching the stage when field scale tests with considerable numbers of cattle under controlled conditions are required. Provision for these is being made at the Council's Field Station at Compton which owes its inception to proposals made to the Council by their *Brucella abortus* Committee. At this station work on pigs and poultry is also being arranged; a herd of pigs of known history is available for investigations on certain aspects of the problem referred to in the last paragraph, and poultry from a nucleus stock inbred in lines showing, respectively, resistance and susceptibility to fowl paralysis are being taken over from the Wellcome Physiological Laboratories at Beckenham as material for a long-range breeding experiment on this disease.

Seven special Committees of the Council are charged with the co-ordination and scientific supervision of research on the major diseases of farm animals, and have submitted reports covering the work in progress during the period under review. They are the Joint Committee on Tuberculosis formed jointly with the Medical Research Council, the Committee on *Brucella abortus* infections in Animals (Contagious Abortion) and Man, appointed in consultation with the Medical Research Council, the Committee on Johne's disease in cattle and sheep, that on Braxy-like diseases of sheep, that on Swine fever, Necrotic enteritis and similar diseases of pigs, that on Fowl paralysis and similar diseases and Coccidiosis, and that on Helminths of economic importance (animals section).

The Committee on *Brucella abortus* infection was reconstituted in 1936 so as to merge the pre-existing Scottish Committee on the same subject with the Council's Committee. It has been a source of gratification to the Council to receive substantial assistance towards the cost of the work in which this Committee is interested from the Milk Marketing Board in England, while in Scotland the balance of the considerable sums raised from the Scottish Milk Marketing Board, Agricultural Societies and private sources are now in the hands of the Scottish Board of Research in Veterinary Science.

Three other special Committees have charge of scientific work on subjects in which animal disease is involved to a greater or less degree. They are the Joint Committee (with the Medical Research Council) on Iodine deficiency and Thyroid disease, the Committee on Nutrition in relation to Disease appointed in consultation with the Medical Research Council, and the Committee on Equine Research. The last-mentioned of these is discussed in this section of the Report, as the main interests of the Equine Research Committee hitherto have been in the diseases and disorders of horses.

The Joint Committee of the Agricultural Research Council and Medical Research Council on Tuberculosis.

The Joint Committee has lost through death the services of a very valuable member, Captain S. R. Douglas, who had also served on the former Tuberculin Committee of the Medical Research Council. Professor G. S. Wilson was appointed in his place.

Research on tuberculosis financed directly by the Agricultural Research Council or with its concurrence and advice has covered a considerable field, and it is not possible to separate completely the work which is chiefly of interest to the Agricultural Research Council from that which is more directly the concern of the Medical Research Council in describing the general advance of knowledge. Research work with direct agricultural bearing may be considered under two main headings, (1) Eradication of tuberculosis from herds by tuberculin testing, and the rearing of healthy stock, and (2) attempts to produce immunity by vaccination.

The methods of eradication with the use of tuberculin have been practised in this country for many years to some extent and tubercle free herds have been formed, but the number of herds thus dealt with has been very small. The introduction by the Ministry of Agriculture and Fisheries of the Attested

Herds Scheme with its recent modifications has made it more necessary than ever to perfect the technique of tuberculin testing. It has repeatedly been demonstrated in this country, the United States and elsewhere, that herds free of tuberculosis can be established and maintained by regular testing, elimination of reactors, disinfection and isolation and by rigorous testing and quarantine of newly introduced cattle, if additions to the herd from outside cannot be avoided. Nevertheless, further research on details of the manufacture of tuberculin and the application of the test have been called for by occasional difficulties in interpreting the results of the test. The Tuberculin Sub-Committee of the Joint Committee was set up to investigate a number of questions at issue. After careful investigation the Ministry had decided to adopt the double intradermal test on the neck for the official test, so that most of the experiments carried out for the Sub-Committee have been applied by this method. The Tuberculin Sub-Committee at their meeting on the 27th March, 1936, received through the Joint Committee a letter from the Ministry of Agriculture and Fisheries stating that the Ministry proposed to exercise powers under Part II (Regulation of Manufacture, etc. of Veterinary Therapeutic Substances) of the Diseases of Animals Act, 1935, and to issue an order laying down standards for tuberculin for testing cattle. The Sub-Committee were asked for their observations. At the request of the Sub-Committee Professor J. B. Buxton and the Secretary, Mr. G. W. Dunkin, undertook to draw up suggested regulations for consideration by the Joint Committee. A draft Schedule of provisions applicable to tuberculin intended for testing cattle was approved by the Joint Committee in July, 1937, and sent to the Ministry. The action of the Ministry in laying down tests to ensure the strength, purity and specificity of tuberculin will afford a very important protection to owners of cattle against the sale of inferior or useless preparations under the name of tuberculin.

Different methods of preparing tuberculin have been investigated at Cambridge by Professor Buxton and Mr. Glover, and there has been close communication between the Public Health Service and the Bureau of Animal Industry in the United States and the Joint Committee and workers in this country. It has been found that tuberculin made by growing tubercle bacilli on simple synthetic culture media is preferable to that made with broth as was formerly the custom, on account of the higher specificity of the reactions and the greater accuracy with which they can be interpreted. It was also shown that repeated inoculation with unheated tuberculin sometimes sensitised a normal animal, so that a slight reaction was produced at a subsequent test. It was therefore concluded that tuberculin which has been concentrated by heat or heated sufficiently in the course of preparation is to be preferred to an unheated preparation. The necessary concentration of tuberculin grown on synthetic media may be carried out by precipitation or by heat, if the product is sterilised by heat or otherwise heated sufficiently to denaturate the protein derived from the bacilli. The use of synthetic medium tuberculin as well as broth grown tuberculin was recognised in 1934 by the Ministry of Health.

Experiments on methods of applying the test showed the need for care in choosing a spot on the neck which was not too near a former recent intradermal inoculation, or in the case of the second injection in the double test sufficiently near the first injection. Difficulty in exact diagnosis by the tuberculin test may arise if a bovine is infected with the avian form of the tubercle bacillus derived from poultry. Such an infection is of little importance in cattle, except that it may lead to a slight reaction with ordinary bovine tuberculin which is not easily distinguishable from one due to infection with the bovine bacillus. The use of tuberculin prepared from the avian bacillus may assist the diagnosis.

Studies of four cases of cattle believed to be infected with the avian type of *B. tuberculosis* have been published from the Cambridge Institute of Animal Pathology. The cattle came from a T.T. herd and from three of them the avian bacillus was cultivated and chickens were infected with the cultures. The cattle had been infected by the alimentary route. During life the three cattle with active lesions gave good reactions with avian tuberculin.[1] In cattle infected with Johne's disease slight reactions with bovine tuberculin are sometimes obtained, and quite commonly with avian tuberculin. Other experiments on the technique of tuberculin testing were also carried out at Cambridge and the results are being published by the Agricultural Research Council as a Special Report.

In the United States of America and in Canada small nodules in the skin of cattle have been described which contain bacteria resembling tubercle bacilli but without any signs of tuberculosis in the glands or internal organs. These nodules may be associated with a slight reaction to tuberculin. They are, in most districts, of very infrequent occurrence, but occasionally may be found in as many as 1 per cent. in a herd. Similar nodules have been recorded in this country from the Ministry's Veterinary Laboratory at Weybridge: the reaction to tuberculin in these animals was very slight and inconstant.[3]

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[1] The references are to the List of References to work on Animal Diseases on pp. 282–284.

Dr. A. Stanley Griffith has published a valuable paper on naturally acquired tuberculosis in various animals.[4] He points out that the bovine type of tubercle bacillus is responsible for the greater part of tubercular disease, especially the generalised and fatal forms, occurring in domestic animals, and for a not inconsiderable amount in human beings. Besides the well-known high proportion of cases due to bovine bacilli in the tuberculosis of young children, the recent observations on the occurrence of human pulmonary consumption due to infection with the bovine type in Great Britain [5] [6], and also in Denmark and Germany, have emphasised the virulence of the bovine bacillus.

Tuberculosis due to the avian bacillus [4] [10] may occasionally infect the pig, ox, sheep, goat, horse, guinea-pig or rabbit, and even marsupials in the Zoo., but it is rare in farm animals except the pig, and is seldom found except in fowls. The human form of the bacillus has a narrower range, but all three types may infect the ox, pig, horse, guinea-pig or rabbit. Griffith [11] has also published an account of experimental infection of rats, mice and voles which shows that these animals can be infected by inoculation, and that then the disease runs a slow course to a fatal ending. Mention may also be made of an obscure disease in field voles recently investigated by Dr. A. Q. Wells[9] working at the Bureau of Animal Population at Oxford. The disease is caused by a bacterium resembling the tuberculosis bacillus, but there is no known connection with any disease of farm animals.

Under the Attested Herd Scheme of the Ministry of Agriculture increasing use is being made of the double intradermal tuberculin test for freeing dairy herds from tuberculosis; and the Scheme is now being extended to include some herds whose chief service to agriculture is in breeding and rearing calves with which to establish and replenish tubercle-free herds. In this connection a small grant was given by the Agricultural Research Council to the University College of North Wales in support of a survey undertaken by Mr. R. F. Montgomerie and Mr. W. T. Rowlands of four breeding areas in North Wales in which the incidence of tuberculosis was unusually low [12] [13].

In December, 1935, 30 farms with 470 cattle were tested and 20 reactors were found; of these 13 had been purchased as calves and 5 were home-bred. In May, 1937, 475 cattle were tested on 36 farms, and on 35 of the farms there were no reactors, whilst on the remaining farm only two reacted, both of which had been purchased. It is hoped that this and other similar breeding areas will be freed from tuberculosis.

The district of Ayrshire in which Mr. Jordan carried out his work for the eradication of tuberculosis whilst stationed at the Hannah Institute, has recently been re-surveyed by Mr. S. J. Edwards from the same Institute. The results, which showed that eradication had made substantial progress, are described in the section of this Report dealing with Dairy Research (p. 296).

The second main field of research in the control of tuberculosis in cattle is concerned with vaccination. Eradication of tuberculosis by the aid of tuberculin testing is most useful in self-contained herds, but is scarcely applicable to those into which new animals are often introduced. It is with a view especially to discovering a method of dealing with the latter that the use of various vaccines is being explored. Research on vaccines intended to increase the resistance of cattle to tuberculosis has been continued at Cambridge. Vaccines made with dead tubercle bacilli have long been known to be capable of raising the resistance to a slight extent and have recently been further examined, but no method has given sufficient encouragement to justify an extensive trial. Attention has been drawn to a " dead " vaccine made by Mr. Spahlinger which he has used for calves on the Continent. A trial was also made by him in Norfolk in 1929-32, but uncertainty as to whether the vaccine could correctly be described as " dead " and the lack of certain details in the published accounts of the experiment detracted from the value of the very satisfactory results claimed. The Government of Northern Ireland reported in 1935 an experiment on 32 calves which was begun in 1931. Mr. Spahlinger vaccinated 21 of these calves and they were later given a dose of virulent tubercle bacilli. The Report was reviewed by the Joint Committee who were of opinion that though the experiment was not entirely satisfactory some degree of resistance had been given by the vaccine. They concluded that a case had been made out for further investigation and advised that a thorough test should be carried out in this country if Mr. Spahlinger were found willing to supply vaccine in sufficient quantity for the inoculation of a suitable number of animals. They also urged that until the vaccine had been shown by further and extended experiments to be effective against natural, as well as experimental, methods of infection its practical application should be deferred [14]. The Joint Committee, in consultation with the Ministry of Agriculture, suggested a suitable experiment which should be undertaken on a large number of calves if Mr. Spahlinger would supply sufficient vaccine for the purpose. Mr. Spahlinger said that he would do so as soon as possible, but has not provided any so far. In the meantime it is understood that the Government of Northern Ireland has undertaken a further and much larger experiment.

The use of a live vaccine is practised in France and several other Continental countries where there is a system of vaccinating calves with living vaccine consisting of a strain of bovine tubercle bacillus, known as B.C.G. (Bacillus Calmette-Guérin), which is so much attenuated that it produces no disease but affords protection against infection with a virulent strain. Experiments at Cambridge previously reported have confirmed the claim that the vaccine made from cultures grown at Cambridge is harmless and when inoculated intravenously into calves confers marked protection lasting three to nine months against a test dose of a highly virulent culture. A review of the literature on the immunity produced in calves by the B.C.G. vaccine given intravenously or by the mouth, including the Cambridge work, up to the end of 1935 has been published[2]. The experiments already reported were made on a small number of animals under rather artificial conditions. Further experiments are now being carried out on a larger scale and in a form more nearly approaching farming conditions, with repeated inoculation of calves at six months intervals and their subsequent exposure to infection either by one final feed on infected milk or by repeated small doses, or again by allowing them to mix with an infected herd. These experiments should yield results in 1938 or 1939. A trial was also made of a vaccine made of B.C.G. coated with gum and suspended in olive oil.

Towards the cost of this work the Agricultural Research Council have approved grants from the funds placed at their disposal amounting in all since the 1st October, 1934, to £6,130, of which £1,312 was for each of the two years from the 1st April, 1936.

Experiments by Colonel Maddock at Reading, which were reported in 1933, showed that tubercle bacilli artificially mixed with soil and dung could survive in the open in summer for 152 or 178 days, as shown by guinea-pig inoculation. In 1934 an attempt was made to infect guinea-pigs by allowing them to feed on growing grass which had been heavily infected artificially with bovine tubercle bacilli, but none of the guinea-pigs became infected though kept for many months; some were even allowed to graze on the day following the contamination of the grass. That living bacilli were present on the grass was shown by the subcutaneous inoculation of guinea-pigs. In a further experiment a large proportion of the guinea-pigs fed on cut grass which had been very heavily infected became tuberculous. Six calves also were fed on grass which was very heavily infected on four occasions, once a month during the experiment; of these five became infected under the very severe conditions of the experiment; the calves began to feed on the grass on the day after its first contamination [15]. In order to imitate more nearly the conditions on a farm two further experiments were made in 1934-36 and reported in 1936 [16]. In the first of these experiments a paddock was infected by three calves which were passing virulent tubercle bacilli in their dung as the result of being fed with infective material from tuberculous cows. After three weeks these calves were removed and their dung spread and after the grass had grown two fresh healthy calves were turned on to each of three separated divisions of the paddock, and allowed to graze for three weeks. None of the last six calves showed any sign of tuberculosis though kept for three months.

In the second experiment a paddock was heavily infected by allowing a tuberculous cow passing very large numbers of tubercle bacilli in her dung to graze on it for a month, from the 25th February to the 1st April; the cow was removed on the 1st April, the dung spread and six healthy calves were admitted to separate parts of the paddock, which had been divided in two, three calves on the 13th May and three on the 11th June. On the 7th July all six calves were put on fresh pasture and remained healthy till killed nine months later; further calves were also put on the same pasture later and remained healthy. Some of the dung of the tuberculous cow which had been used to infect the pasture, and had been lying undisturbed under a cover, was found to be infective for guinea-pigs after 42 days.

These experiments, towards the cost of which a grant of £100 was made from the funds at the Council's disposal to cover their continuation from the 1st January to the 30th June, 1936, show that a pasture which has been occupied by infected cattle is unlikely to infect fresh cattle after an interval of a few weeks. It also suggests that infection in adolescent cattle is more taken in through the air passages than by the alimentary canal.

A recently developed technique for detecting tubercle bacilli in milk has been tested in the Manchester Public Health Laboratory. The method consists in making a rapid search with a low power of the microscope of a suitably prepared and stained film of a centrifuge deposit for certain special groups of cells. These are then examined with a high magnification for tubercle bacilli. The bacilli when present are almost invariably in these characteristic cell-groups. Parallel series of examinations of milks by this new technique and by guinea-pig inoculation gave very nearly identical results. If further stringent and more extensive trials confirm these results the method may prove of great practical value on account of its rapidity. The method appears to be far more accurate than the formerly used microscopic methods if all the details of the technique are carried out [7] [8] and milk from each quarter is examined separately.

Committee on Brucella abortus Infection in Animals and Man.

Since the last Report, the Committee of the Agricultural Research Council on *Brucella abortus* infection in Animals and Man and the Scottish Committee on Contagious Abortion in Cattle have been dissolved and replaced by a new Committee appointed by the Agricultural Research Council, containing three Scottish members. The funds collected in Scotland for work on this subject were transferred for administration to the Scottish Board of Research in Veterinary Science.

As a consequence of the purchase by the Agricultural Research Council of the Compton Manor Estate for a Field Station, the Committee have been asked to give further consideration to planning of the intended experiments on contagious abortion and to the suggested lay out of the buildings for the experimental animals. The details have been discussed, members of the Committee have visited Compton and proposals have been put forward. The Committee have agreed in accordance with former decisions that for the present the experimental work in progress at various research centres should be limited for the most part to small animals, and should be largely directed to preliminary enquiries intended to lead the way to those experiments which will be carried out at the Field Station.

As in the case of tuberculosis, the two chief methods of combating the disease are the systematic accurate diagnosis of infected animals and their isolation or removal from the herd, and on the other hand, attempts to raise the resistance of the cattle to infection by means of a vaccine. The first, or eradication method, entails testing all the cattle in a herd at regular intervals of two to six months and is most suitable for a self-contained herd, if possible on a farm where the space and conditions are favourable for segregation of infected animals and isolation of all animals at calving time.

The chief method of routine diagnosis is by testing the blood serum for agglutination of the *Br. abortus*. This is a very reliable test as a rule, but during the earlier stages of infection or of an acute exacerbation of the disease the agglutinins may be temporarily absent or only present in very low concentration, as happens in other acute infective diseases. Diagnosis may also be made by bacteriological examination of the discharges after calving or of an aborted foetus, by direct culture or by inoculation of guinea-pigs, and by the examination of the milk by guinea-pig inoculation.

Strains of *Br. abortus* vary much in their agglutinability and in the readiness and the specificity with which they react to serum. It is important therefore that the suspension of bacteria used for diagnosis should be uniform in composition and sensitiveness. In order to secure as high a degree of uniformity as possible the bacterial suspension used in the work for the Committee is all made in one laboratory, at the Royal Veterinary College, where it is tested before issue with an agglutinating ox serum preserved in a dry state[17]. Each new batch of suspension is tested against the same standard serum. It is hoped that the International Standards Committee will adopt the same serum as an International Standard for human and bovine diagnosis. The question of what dilution of bovine serum should be regarded as diagnostic in the agglutination test has been much under discussion and further observations are being accumulated. There is some evidence that agglutination with a less dilute serum should be regarded as significant of infection during pregnancy, and perhaps under other special conditions. In the hope of supplementing the agglutination test a skin reaction with an extract of *Br. abortus,* known as brucellin, and used in a similar way to tuberculin, has been tried in some other countries. A series of parallel tests has been made at Weybridge and also at Liverpool but very little evidence of its utility has been obtained so far, since usually the two tests have agreed. Some observers, however, state that occasionally an infected animal is detected by its reaction to brucellin when the agglutination reaction with its serum is negative.

A special form of the opsonic reaction with the serum of cattle has been used in the United States to distinguish susceptible, infected and immune animals, but a careful investigation at Wye failed to confirm its value[18].

The Committee have given much attention to the details of the scheme of eradication begun in 1933, of which a brief account was given in the Council's last Report. It is intended that it should be continued till the autumn of 1938, when the results of the five years work will be examined. Since, however, 66 per cent. of herds in England are " flying herds " the extent to which " eradication " can be applied in this country with existing knowledge is only limited. Work under the scheme was undertaken in 1933 at five centres, namely, The Veterinary Laboratory of the Ministry at Weybridge, the Research Institute in Animal Pathology at the Royal Veterinary College, the South-Eastern Agricultural College at Wye, the Institute of Animal Pathology at Liverpool, and the Hannah Institute for Dairy Research, Ayr. An eradication experiment was also made for about one year from the Rowett Research Institute, but the local conditions were not found suitable and the work there ceased. The Veterinary Investigation Officers at King's College, Newcastle, and at Harper Adams Agricultural College have also undertaken some eradication work, and have been supplied with standard bacterial suspension by the Committee.

The Laboratory of the Ministry at Weybridge has continued to make tests and to give advice on a number of herds, and has also undertaken some special investigations on the significance of persistent low titre agglutination in a few cows which have been purchased and kept under observation[19]. The milk of 309 cows whose blood serum gave negative results with the agglutination test was examined and from two of these the *Br. abortus* was isolated, showing that a negative agglutination test does not necessarily exclude infection of the udder. From the milk of 35 per cent. of a total of 700 cows examined the *Br. abortus* was isolated. The eradication programme of the Institute in Animal Pathology of the Royal Veterinary College began some years before 1933 and has been continued in seven herds; the results have been good except in one herd. From the College at Wye attempts at eradication have been carried out on a large number of herds (about 24); many of these have been "flying herds" and the conditions for isolation have been very varied; special observations have been made on cows giving low-titre agglutination reactions, and some of these have been sent to Weybridge for further examination. From the Institute at Liverpool some nine herds, comprising about 650 cattle, have been under test and observation and the results have on the whole been encouraging. At the Hannah Institute fifteen herds have been under control by agglutination and segregation, and some satisfactory results have been obtained, but here too difficulties have arisen in certain herds and attempts have been made to detect obscure sources of infection.

In the herds which were tested from the Rowett Institute, 31 per cent. of the cattle gave a positive reaction. The result of the year's work was regarded as inconclusive, since in most of the infected herds segregation was not possible.

In some of the areas in which eradication has been attempted farmers have been inclined to withdraw their co-operation in the scheme after two or three years when a series of tests on their herds has given negative results, and they have unwisely relaxed precautions with consequent recurrence of disease.

A serious outbreak of contagious abortion in the pedigree herds at the National Institute for Research in Dairying at Reading was the object of visits by a Sub-Committee at the request of the Director. Careful enquiry showed the great difficulty of the situation and the limited accommodation which had not been designed to deal with an epizootic. The Committee tendered their advice and the Agricultural Research Council have been glad to learn that the health of the herd has very much improved of late.

In all the areas included in the eradication scheme the well-known difficulties associated with the absence of agglutinins in the blood serum shortly before abortion have been encountered, and in some herds cows have been found in which the diagnosis is uncertain because the serum constantly gives agglutination but only in very slight dilution, e.g., 1 in 10. As mentioned above a special effort is being made at Weybridge to find out whether this titre has any constant significance.

Valuable data on the method of eradication have been accumulated and, so far, the experience gained indicates that control is practicable on most self-contained farms, but final conclusions cannot be drawn.

Another enquiry which has been begun at Weybridge is on the progress of calves exposed to infection when very young, to ascertain their serum reactions and find out whether they all become infected, recover and remain immune, or whether they are liable to infection at a later date.

Turning next to research and experiments on immunity, it became clear at an early stage of the Committee's existence that experiments with cattle on the production of immunity with vaccines and on some other aspects of contagious abortion could only be conducted profitably on herds owned by the Agricultural Research Council and under the control of the Committee. The nature and limits of the research which can be undertaken before the field station is established and equipped have therefore been discussed at various times. It has been decided that until such time as the Field Station of the Agricultural Research Council is available the Committee should defer any experiments on bovine animals which, on account of the existing conditions for experiments or the insufficient number of animals used, could not be expected to give a satisfactory answer. However, certain experiments with small animals are appropriate to the present conditions and some subsidiary tests with small numbers of cattle.

The chief experiments, therefore, which have been possible during the last few years concern preliminary questions which nevertheless are of great importance. To aid in these experiments the Agricultural Research Council appointed Mr. F. W. Priestley to be a member of their scientific staff with effect from the 1st August, 1936, and posted him to assist Dr. A. D. McEwen at Wye.

The fundamental question of how long the products of an abortion and faeces or urine can remain infective demanded further investigation. At the Institute of Animal Pathology at Cambridge it has been shown that from an aborted foetus left lying undisturbed on the ground in the open the *Br. abortus* could be recovered after 142 days, or if the membranes were placed in water the infectivity remained for 156 days, in liquid manure for 79 days, but in urine for less than 7 days [20] [21].

The small animal most generally used for laboratory experiments has been the guinea-pig[22]; white mice and rats have not been found so suitable, though mice can usually be infected with *Brucella abortus* from cattle[23]. Workers in Palestine claim that the Syrian hamster is more readily infected, that the incubation period in this animal is shorter, since it shows signs of infection in a week, and that moreover the disease in the hamster more closely resembles that in a bovine since the hamster aborts if pregnant and transmits the disease to others by contact.

Inoculation of the guinea-pig is the usual method of detecting *Br. abortus* in milk or other materials if contaminated with other bacteria. These animals have also been used for studies of the virulence of different strains of *Br. abortus* and of the immunity induced by vaccines. The development of infection in guinea-pigs is slow, and in diagnostic trials these animals must be kept four to six weeks before being killed and examined.

Tests of the virulence of strains of *Br. abortus* have been carried out on guinea-pigs, which can be infected by instilling a drop of a suspension of the bacilli into the eye or by subcutaneous inoculation. The degree of activity or virulence of different strains is estimated by the size of the dose needed to produce a given degree of infection in the test animal, and by the state of infection as decided by the size of the spleen and the number of bacterial colonies recovered from a given amount of tissue of the spleen or other organs. The method of infecting cattle by dropping culture in the eye is being tested in a herd in the field.

Different strains have very diverse virulence. Some non-virulent strains have been tested and one strain in particular has been fully examined at Wye. It has been found to be quite harmless to guinea-pigs and to pregnant heifers if inoculated subcutaneously, but could produce abortion if given intravenously. It also gives a very definite measure of protection to guinea-pigs against a virulent strain. At Wye also during the last five or six years several series of important experiments on the virulence of different strains and on the production of increased resistance by vaccines have been carried out with guinea-pigs. The infection of these animals resembles that of cattle in several respects. In pregnant guinea-pigs the uterus becomes infected and abortion occurs. Little or no evidence of increased resistance was obtained with dead vaccines which had been killed with formalin or by heat. Living vaccine however, made with a particular non-virulent strain of *Br. abortus*, gave a very considerable degree of protection against a fully virulent strain given in a dose which infected all or nearly all the control unvaccinated animals. Interesting observations were also made on the course of infection and the rise of agglutinins in the blood following on infection or administration of a live vaccine. Infection of male guinea-pigs was also studied and their protection with live vaccine demonstrated.

The immunity induced in guinea-pigs with a live vaccine was not absolute and in some experiments irregular; the identity of the non-virulent strain which was used appeared to be of considerable importance as also its history in respect of previous culture and treatment.

At the laboratories of the Animal Diseases Research Association at Moredun an intensive study has been made on a large scale to determine what prophylactic value, if any, for guinea-pigs is possessed by vaccines made from killed cultures. The first stage of the research involved the infection of 300 guinea-pigs and the killing and post-mortem examination of three of them daily. Observations were made by cultures on the time after inoculation at which infection was at its maximum and when it began to decline, and the agglutinating properties of the blood were also tested during the whole period of the experiment. After this preliminary investigation of the course of infection, the effect of dead vaccines on the disease was tested. Three types of material were used to make the vaccines, and heat or formalin was used to kill the bacteria in them. Five doses of one of the vaccines was given to each guinea-pig in a group of fifteen, and a similar group was used for each kind of vaccine. Fourteen days after the last dose of vaccine a test dose of virulent culture was given, the course of the infection observed and the agglutination with the serum of the animals tested throughout. The results did not show any evidence of efficient protection of the guinea-pig with dead vaccine. Later a new series of similar experiments was made using certain proprietary dead vaccines and also non-virulent living vaccines. Some degree of protection was afforded by the live vaccine but only slight protection with the dead preparations. Further studies were also planned to ascertain the degree of immunity following infection with virulent cultures and whether the immunity persists after the infection has died out.

At the Cambridge Institute of Animal Pathology an oleo-vaccine made by coating living virulent *Br. abortus* with gum arabic and suspending them in olive oil has been given subcutaneously to guinea-pigs and a few cattle, but evidence of resulting general infection has shown that the bacteria did not remain confined to the site of inoculation as had been hoped.

Trial is being made of the method of preserving cultures of special strains of *Br. abortus* in a dry state so that they not only retain their vitality for many months but will also in all probability remain unchanged in their special infecting and immunising properties.

Certain other aspects of *Brucella* infections have received some attention. Wild rats from infected farms abroad are said to have shown evidence of infection in that their blood serum contained agglutinins[24]. At Cambridge wild rats when inoculated became infected and transmitted the disease to others.

The infection of fowls is reported to be not uncommon in some places in the United States, but examination of the blood serum of fowls at Weybridge gave no evidence of infection.

The transmission of the disease by bulls to healthy heifers has been demonstrated in Denmark, and the whole subject of the transmission of Brucellosis to animals and man has been recently summarised by the *Office Internationale des Epizooties*[25]. A number of cases of undulant fever due to infection of man with *Br. abortus* occur in Great Britain annually. These have been specially investigated in England and Wales by Sir Weldon Dalrymple-Champneys[26], and in Scotland by Beattie, Smith and Tulloch[27]. The diagnosis cannot as a rule be made without examination of the blood-serum for agglutinins. It is probable that considerably larger numbers occur than have been investigated and recorded. Cases sometimes come to light three or more years after the onset of the illness. In 1936 three additional were collected in relation to an onset in 1933, four referable to 1934 and six to 1935.

The average duration of fever in 259 cases included in this series, as far as can be ascertained, was 12·6 weeks, with an addition of several weeks convalescence to the period of incapacity from work. Undulant fever is therefore a serious disease, though only eleven deaths are known to have occurred in a total of 373 cases, i.e., 2·9 per cent.

The following table concerns 338 cases which were investigated in England and Wales showing the years in which their illnesses began.

Year of onset.	*Number of cases.*
1930	30
1931	42
1932	65
1933	62
1934	52
1935	39
1936	48

Some evidence of possible origin was obtained in 275 cases. Two hundred and sixty-six of the 275 or 96·7 per cent. had taken raw milk or cream and of them 19 had also been in contact with probably infective animals. In London 22 cases are known to have occurred and though 90 per cent. of London milk is pasteurised, 14 of the 22 were drinkers of raw milk.

Recent work has suggested that *Br. abortus* is susceptible to the bactericidal action of the gastric juice. In tests both with acid solutions and with gastric juice, *Br. abortus* was found to be the most readily destroyed of several intestinal pathogens tested[28].

In some countries there is evidence of a considerable amount of infection amongst veterinarians, presumably as the result of direct contact with infective animals, but this has not so far appeared very obvious as the result of examinations of blood serum in Great Britain. Sometimes infection occurs as the result of handling infective carcases. Though horses may undoubtedly have abscesses infected with *Br. abortus,* especially in cases of poll-evil and fistulous withers, cases of infection in man are not known to have arisen in this country from any other animal than a bovine.

Grants have been made from the funds at the Council's disposal in support of the work on contagious abortion under the Committee's co-ordination at a number of centres. For that in progress at the Veterinary Laboratory of the Ministry of Agriculture and Fisheries, grants amounting to £4,930 were approved to cover the period from January, 1936 to March, 1938. For the work at Wye College a total of £4,875 was sanctioned for the period from the 1st October, 1935 to the 30th September, 1938. The grants to the Moredun Research Institute for the same period amounted to £750 and to the Hannah Dairy Institute £812 10s. The work at the Royal Veterinary College in London was aided to the extent of £307 10s. during this period and the Cambridge Institute of Animal Pathology received a small grant of £50 to cover work during the year from the 1st April, 1936 to the 31st March, 1937. The eradication work at Rowett Research Institute was aided by a grant of £125 for the year from the 1st October, 1935 and that supervised from Liverpool University by grants totalling £445 from the 1st October, 1935 to the 31st March, 1938. In addition to these grants the Council has provided for the salary and expenses of a scientific officer appointed by them for research work on contagious abortion and posted to assist Dr. McEwen at the South Eastern Agricultural College, Wye.

To cover a part of this expenditure on research on contagious abortion the English Milk Marketing Board made contributions to the Council amounting to £4,000 during the two years under review. Contributions to the work in Scotland, additional to those mentioned above, were made by the Scottish Milk Marketing Board and certain Societies to the Scottish Committee on Contagious Bovine Abortion and subsequently to the Scottish Board of Research in Veterinary Science. These amounted to £483 between the 1st October, 1936 and the 31st March, 1938. The Committee on *Brucella abortus* infection in Animals and Man have expressed to the Council their appreciation of this valuable aid towards the carrying out of their programme of research.

The Committee on Johne's Disease in Cattle and Sheep.

The importance of Johne's disease or Paratuberculosis has long been recognised, but its gradual onset and the slow and sometimes intermittent progress add peculiar difficulties to attempts to deal with it effectually. Efforts to ensure early diagnosis have been made for some years by intradermal injection of a product from Johne's bacillus, called johnin, used in the same way as tuberculin[29]. The method of making johnin has been improved and the bacillus can now be grown on simpler media than were used formerly. Though johnin has been used for some time for diagnosis and elimination of reactors from herds, it is known that certain fallacies may interfere with the accuracy of the method and experience is needed to reduce errors to a minimum. In order to put the interpretation on a sound basis and to determine which of several available preparations of johnin is the best, a series of careful tests on cattle two or three days before their slaughter has been in progress. It is hoped to continue the experiment until a hundred cattle have been tested and thoroughly examined post-mortem. The reactions to the I.D. (intradermal) test are being examined by three experienced veterinary research workers and the results compared with the state of the organs found post-mortem. The work is slow and laborious since every suspected piece of intestine, gland or organ, besides being examined microscopically, is inoculated on to culture media and also into animals. Moreover, these cultures and animals must be kept and observed for several weeks or months and then submitted to further examination.

There is considerable resemblance between the bacilli of Johne's disease and tuberculosis, and cross reactions in the I.D. test may occur between Johne's disease and tuberculosis especially when an infection with the avian type of tubercle bacillus is present. In order to make a just comparison between the I.D. test and the post-mortem diagnosis it is necessary to make a very complete search for foci of disease in the glands and tissues. The final results from this series of experiments cannot be complete for about two years.

A disease of sheep closely resembling Johne's disease of cattle occurs in some flocks in this country and has been investigated at Mill Hill[30] and at Wye College. The bacillus found in the sheep differs from the true Johne's bacillus in that it had never been found possible to grow it in culture until within the last two years, and growth is still very difficult to obtain and is extremely slow. The ovine disease can be transmitted to other sheep by feeding and in a few instances it has been communicated to calves. No natural relation between the bovine and ovine diseases has been discovered.

It is hoped that when cases of Johne's disease can be diagnosed with greater accuracy regularly and especially early, before the excretion of bacilli has become profuse, the disease can be eradicated by slaughter and segregation as has already been attempted with a degree of success in some herds.

For the work on the testing of cattle for their reaction to johnin and subsequent post-mortem examination, the Agricultural Research Council placed at the disposal of their Committee on Johne's Disease a sum of £500 during the period from the 1st January, 1936, to the 31st December, 1937. For that on the allied disease in sheep an additional grant of £60 was made for one year from the 1st January, 1937, to the South Eastern Agricultural College, Wye.

The Committee on diseases of Sheep.

In the last Report of the Council it was stated that the Committee had decided to institute a survey of the diseases of sheep due to anaerobic bacilli. The work was begun in the autumn of 1935 and by the end of May, 1936, Mr. R. S. Roberts, who had been seconded from Wye College to undertake the survey, reported on the occurrence and distribution of these diseases in England, especially the West and South-West counties, and in all but one of the counties of Wales. While engaged on this work Mr. Roberts was given laboratory accommodation and assistance at the Institute of Animal Pathology at Cambridge in order that he could examine the material that he collected. Other research work on anaerobic bacilli is in progress at the Cambridge Institute so that Mr. Roberts was able to obtain valuable help in his bacteriological work there. Since July, 1936, the survey has been extended to Scotland by Mr. Roberts, who accepted an appointment to the Council's scientific staff for three years from the 1st October, 1936. The Committee have made two reports to the Council for the year ending September, 1936, and for the period ending July, 1937.

Sheep Diseases in England and Wales.—Mr. Roberts's report regarding England and Wales was reviewed by the Committee in July, 1936. In making the survey attention was given to the relations between methods of husbandry and the types of disease present in the flocks, and correlation was often found in different areas between the methods of grazing and the prevalence of similar diseases. The forms of disease associated with infection with anaerobic bacilli were classified by Mr. Roberts as:—Entero-toxaemia of adult sheep, Braxy, Pulpy Kidney, Lamb Dysentery, and Parturient Gas Gangrene. The data collected indicate that on 59 of 390 farms there was a mortality of over 1 per cent. probably due to entero-toxaemia. This disease is characterised by a short illness and rapid decomposition after death; it occurs chiefly in sheep on rich pasture, just before they are moved to hill pastures in early summer; but it also appears when sheep are moved to richer grazing in spring after rough grazing in winter. The maximum mortality recorded was 3·5 per cent. A type of *Bacillus welchii* producing D toxin is the recognised cause of this disease. It apparently does not occur in flocks under conditions of arable management.

Braxy, proper, is associated with another anaerobic bacillus called by Pasteur *Vibrion septique*. It causes sudden death in sheep under one year in autumn and winter. It was reported in 64 out of 65 flocks of which the summer grazing extended up to 1,000 feet. The mortality from braxy in these flocks averaged 4·1 per cent. The state of the pasture or other local conditions are probably important predisposing causes of infection. In North and South Wales the pasturage conditions associated with braxy were very different, which suggested that perhaps two diseases were included under the same name.

Pulpy Kidney disease[31] occurs in sucking lambs and is widespread on Welsh and English grasslands, where it causes an average mortality of 1·25 to 1·5 per cent., but in some cases as high as 5 per cent. The higher mortalities were recorded among lambs born in the early part of the year and fed to be sold fat from April to June. The mortality among later lambs, born in April, was negligible. It is generally associated with *B. welchii,* type D.

Lamb Dysentery[32] is reported from four or five counties in Wales and from parts of England. It is due to infection with a special type of *B. welchii,* and specific antitoxic serum, prepared with strains of *B. welchii* isolated from cases of lamb dysentery, is a very valuable preventive against the disease. Variation in the strains of bacillus and the toxins which they produce makes the manufacture of the serum difficult; nevertheless a good brand of serum is highly effective.

A disease known as parturient gas gangrene occurs in Wales and some of the Western English Counties. It is due to the anaerobic bacillus *B. chauvoei* and is correlated with the practice of penning sheep in small paddocks during the lambing season. An infected wound is generally the basis of the disease.

Another rapidly fatal disease due to a special type of *B. welchii* has been recorded from North Wales, as well as from Romney Marsh, where it was first investigated scientifically and where it is known as "Struck." As mentioned in the Council's last Report a small grant was made to the South Eastern Agricultural College, Wye, for a field test on a large scale of protective vaccination against this disease in the Romney Marsh. Dr. McEwen submitted a report on this test in May, 1936. The mortality among the vaccinated sheep from what was regarded as struck was 1·4 per cent. and among the non-vaccinated, 3·3. There were 7,647 sheep in the former group and 7,645 in the latter.

The above mentioned sheep diseases associated with sporing anaerobic bacilli are not by any means always easy to identify except by the isolation of the infecting bacillus and its subsequent study in the laboratory. In the field a careful consideration of the local conditions may be needed to assist the diagnosis. The classification outlined above forms a useful foundation at the present time as a basis for further research.

Sheep Diseases in Scotland.—In March, 1937, Mr. Roberts presented a detailed report on sheep diseases in Scotland. It had been found unsatisfactory when visiting a large number of farms to confine enquiries to one class of diseases and the Committee authorised Mr. Roberts to extend his report to cover various other diseases met with, excluding those specially investigated by other Committees of the Council.

The Committee's Report to the Council covering the period to July, 1937, included a review of Mr. Roberts' survey of sheep diseases in Scotland. This survey was based on enquiries in the greater part of Scotland, excluding the northern counties. The diseases included in the survey, besides those associated with anaerobic bacilli mentioned above, are Parasitic Gastritis, Pregnancy Toxaemia, Louping Ill, Swayback, Enzootic Abortion, Scrapie, Infectious Pneumonia, Sterility, Myiasis, and Pyaemia of lambs associated with tick infestation.

Lamb Dysentery was found to occur in most of the Scottish hill flocks; complete success in the prevention of this disease is said to follow the use of lamb-dysentery serum given soon after birth, but proprietary powders given by the mouth are often used since they are cheaper and are credited by many farmers with some reduction of the mortality.

Braxy is of importance chiefly in the Western Highlands. It is apparently much less prevalent than it was 10 or 12 years ago, but this change may be due to other diseases having been confused with it formerly. This disease can often be obviated by wintering animals away from "braxy areas." Vaccination is an efficient preventive when the disease cannot be controlled by management of the grazing.

Pulpy kidney is less common in Scotland than in England and Wales, but its incidence may be as high as 3 or even 7 per cent. on "green hill land." Observation suggests that this disease may be controlled by the use of lamb-dysentery serum, and an experiment to determine this question has been planned. The quality and quantity of the food probably act as important contributory causes of this disease by enabling particular types of *B. welchii* to multiply in the intestine and cause toxaemia. The work in progress on sheep nutrition is referred to in Chapter VI.

Louping ill is successfully treated by the immunisation of the sheep against infection with a preventive vaccine which extensive field tests, carried out by the Animal Diseases Research Association, had shown to be consistently satisfactory. The vaccine is prepared at, and issued on a commercial scale from Moredun. Young lambs, however, may contract louping ill and the possibility of immunising them with safety has yet to be determined. At Moredun work is also in progress on tick-borne fever. Recent work indicates that the virus of this disease belongs to the group of micro-organisms known as the *Rickettsia.* Attempts are being made to establish infection in small laboratory animals and to cultivate the organism artificially. Tests of various therapeutic substances against the disease are also in progress.

A good deal of study has been devoted at Moredun to alimentary infection of sheep by *B. welchii,* type D (*B. ovitoxicus*), whose toxin is recognised as responsible for entero-toxaemia. The results of this investigation are being correlated with the work of English observers on lamb dysentery and braxy through the Council's Committee.

Of the other states of ill-health in sheep in Scotland malnutrition appears to be the most serious, though parasitic gastro-enteritis and sterility also figure largely in the records obtained: these are either primary or they may be often, perhaps mainly, secondary to malnutrition and the like. A suppurative disease affecting the joints of lambs, and perhaps secondary to tick infestation, requires investigation. Swayback, abortion, scrapie, infectious pneumonia, and myiasis are all on the programmes of research of institutes with which the Council is in direct touch. Studies on scrapie are being continued at Moredun where, from a field experiment begun some five years ago, a certain amount of evidence pointing to infection through the pastures has been obtained.

Mr. Roberts' report contained a map showing the incidence of certain diseases in the parts of Scotland surveyed; tables were also included for each county separately showing the distribution of different diseases among individual farms. The total number of farmers interviewed was 209 and data were obtained from 254 farms.

The great assistance given by Dr. Russell Greig at the Moredun Institute of the Animal Diseases Research Association and also by the County Organisers is acknowledged by Mr. Roberts.

In their review the Committee make certain recommendations for research on some of these diseases, but they did not find clear evidence of an urgent need to undertake further investigations on the etiology of any braxy-like disease, or of need for exploring fresh means of controlling braxy-like diseases. In the Western Highlands malnutrition appears to be the preponderant cause of losses, though tick-borne diseases, anaerobic bacterial diseases and sterility all play a part. A special investigation carried out by Mr. Roberts on a farm in Argyllshire during May and June, 1937, showed that deficiency of pasturage and not specific disease was responsible for practically all the losses during this period.

Certain of the Veterinary Investigation Officers collaborated with the Committee in the collection and examination of material in cases of mortality from braxy-like diseases in the flocks in their areas. Towards the cost of this work the Council made grants from the funds at their disposal to the University College of North Wales (£120 for the period from the 1st October, 1936, to the 30th September, 1938), King's College, Newcastle (£70 for one year from the 1st October, 1936) and Seale Hayne Agricultural College (£30 for one year from the 1st October, 1936). These grants were made by way of special research grant additions to the respective advisory grants. Towards the additional cost incurred at the Institute of Animal Pathology, Cambridge, in respect of Mr. Roberts' survey, the Council approved grants amounting to £700 from the 1st April to the 30th September, 1936, and £50 as a supplementary grant for the work in the previous year. The grants made by the Council to cover Mr. Roberts' travelling and research expenses amounted to £720 for the year from the 1st October, 1936, to the 30th September, 1937.

The Committee on Swine Fever, Necrotic Enteritis and Similar Diseases of Pigs.

Mr. John Smith, one of the Members of the Agricultural Research Council, undertook to make a preliminary survey for the Animal Diseases Committee of pig diseases and pig problems in this country and presented a report in April, 1937. The report was based on information received from many sources, including contact with many large and small pig-breeders. The evidence collected pointed to a rising mortality in pigs which is referable in great part to the changed conditions in pig-keeping, the increase in the pig population sometimes tending to overcrowding, and the increased need to obtain farrowing all the year round. The most noticeable features associated with ill-health were the high death rate of young pigs up to weaning and the high proportion of wasters and bad doers leading to undue mortality and to serious financial loss through having to feed them longer before they reach pork or bacon weights. In older pigs the chief causes of mortality were swine fever, necrotic enteritis and swine erysipelas. Probably the mortality is far higher than it need be, and there is a demand for an enquiry.

As mentioned in the Council's last Report Mr. N. H. Brooksbank was seconded from the Inspectorate of the Ministry of Agriculture in 1935 to survey the causes of ill-health and mortality in pigs. He made a report on the period from the 1st July, 1935, to 31st January, 1937, during the latter part of which time he had extended his investigations to Scotland. The report contains a great deal of interesting matter concerning the mortality at different ages and seasons from different causes and in different parts of the country, and also data about the sizes of litters and methods of management.

The average mortality under eight weeks was found by Mr. Brooksbank to be about 25 per cent., but in some localities was as high as 40 per cent.; the highest death rate was in the three winter months. Under the age of one week the deaths are said to be chiefly due to crushing, chilling, agalactia of the sow and killing off to reduce the size of the litter. Between one and eight weeks old the most important causes of death are anaemia and scour, which are very often associated and are most fatal at three to four weeks old[34]. Anaemia is apparently easily dealt with by treatment with iron; since iron has been given regularly to the pigs at the National Institute for Research in Dairying at Reading few die during this period after three weeks of age. Anaemia is also said to be successfully dealt with by allowing the piglets to run on pasture or by giving them sods of earth.

After weaning and between eight and sixteen weeks of age the most important cause of death is stated to be necrotic enteritis, which is often associated with worm infestation. It is not prevalent after 16 weeks of age. This disease, which was formerly confused with swine fever, has been till recently believed to be always caused by infection with the bacterium *Salmonella cholerae suis* (*S. suipestifer*). In two recent investigations, however, fatal necrotic enteritis has been described which was apparently induced by an unsuitable diet and cured or prevented by additions to the food. At the Institute of Animal Pathology at Cambridge young pigs on a diet consisting chiefly of white maize developed necrotic enteritis which ended fatally unless the diet was supplemented by the addition of dried yeast or an extract of yeast, whereas on a diet of mixed wheat and barley instead of maize, or of maize with dried yeast, similar pigs throve[35, 36]. At Wye College it was found that the provision of barley-water to which iron had been added (as Parrish's Food), or of dried milk obviated scour and necrotic enteritis, which was found to be a disease associated with malnutrition[37]. During neither of these series of experiments at Cambridge and Wye could *Salmonella* be detected at the post-mortem examinations of the pigs.

In pigs after weaning unthriftiness is common, and is attributed to various causes, e.g., *Salmonella* infection, pig-sick land and worms. In Germany it has been asserted that pig-influenza, as described by Shope in America, is prevalent in a mild form in young pigs and leaves a prolonged period of ill-health after the acute stage. Unthriftiness in pigs at this age is said to be less common under out-door rearing.

In adult pigs the chief causes of ill-health and mortality are swine fever and swine erysipelas. Vitamin A deficiency in the diet is also probably important.

After considering Mr. Brooksbank's report the Committee recommended that he should concentrate attention upon obtaining more detailed information from a small number of selected piggeries, and that his further activities should be reviewed at the end of the financial year 1937-8. They thought that it was clear, both from this survey and Mr. John Smith's report, that the problem of pig mortality was much wider than a purely pathological one, and that management, nutrition and heredity all played a part. They suggested that the borderline between problems of housing, feeding and production and problems of preventible mortality should be explored, and that studies should be made at a few centres, including Compton, with the object of defining the conditions under which it was possible to achieve minimum losses at various ages under optimum conditions of husbandry and protection from disease.

Swine erysipelas is under investigation at Cambridge, but progress is slow. The strains of the causative bacillus, *Erysipelothrix*, vary very much in their activity and their component antigens. It is difficult to infect pigs with cultures, and evidence of reaction to vaccines obtained by examination of the blood serum is very slight, so that experiments on the value of vaccines are often inconclusive. Dead vaccines, however, can be shown to protect pigeons against infection. Further research on this disease is being undertaken at Cambridge, and the grant of £400 which was made from the funds at the Council's disposal towards the cost of the work at the Institute of Animal Pathology for the year commencing the 1st October, 1936, has been renewed at the same rate for the current academic year. The work during 1936-7 included studies of the antigenic relationship of various strains of *Erysipelothrix* in order to select suitable strains for the preparation of vaccines, and studies of various indirect methods of assessing immunity following vaccination. An attempt is being made to raise by artificial methods the virulence of cultures of the causal organism for the pig so as to provide a direct method of testing immunity. A study will also be made of the survival of the organism outside the body and its possible power of multiplying in soil and manure. Further serological tests for diagnostic purposes and further field tests of vaccines are also in progress.

Work on swine fever and necrotic enteritis to be undertaken at the Veterinary Laboratory of the Ministry of Agriculture and Fisheries was recommended by the Committee in their first Report in 1933. The Committee's second Report in September, 1935, stated that little progress had been made in these investigations up to that time, and a third Report in October, 1936, showed that there was a lack of adequate staff and facilities at Weybridge and the work was still in much the same position as in 1933. The Committee urged that the Council should do everything that was possible to expedite research on these diseases at Weybridge since the delay, particularly in respect of research on necrotic enteritis, was seriously militating against the public policy of extending the pig industry. They considered that two whole-time assistants should be appointed for work on pig diseases and that additional permanent animal accommodation and maintenance was required.

The Council endorsed these recommendations and decided that, as an immediate measure, a sum of £1,400 should be provided from the funds at the Council's disposal for research, especially on necrotic enteritis, during the year from the 1st April, 1937. This sum was intended to provide for temporary animal accommodation, the salary of a temporary research assistant and maintenance costs.

In June, 1937, an assistant was appointed to the permanent staff at Weybridge for work on pig diseases and some of the necessary accommodation for the work was approaching completion. The second (temporary) assistant, however, had not been appointed up to the end of the period covered by this Report.

The Committee presented a fourth Report in September, 1937. In this they urged that the second permanent post for work on pig diseases at Weybridge, previously recommended, should be filled as soon as possible. This recommendation was supported by the Council's Committees on Animal Diseases and Animal Nutrition, who advised the Council that the question of making further temporary grant aid by way of a special research grant to Weybridge should be taken up with the Ministry. The necessary financial provision for this has been made in the estimates for 1938-9.

In 1935 Messrs. Imperial Chemical Industries, Ltd., made a grant to the Council of £500 for the purpose of investigating the action of disinfectants on the virus of swine fever. Dr. G. Slavin was appointed to undertake the investigation at the Ministry's laboratory at Weybridge with effect from October, 1935. He completed the examination of a number of disinfectant compounds in comparison with a specially devised chlorine disinfectant, and also a study of the viability of the virus at different hydrogen-ion concentrations and under natural conditions. A report by Dr. Slavin on the work will be published shortly.

The Committee recommended an investigation into the possible association of necrotic enteritis with infection of the pigs by *Ascaris lumbricoides,* and a study of the pathogenicity of these worms to the pig, to be carried out at Weybridge by Mr. E. L. Taylor. This recommendation was adopted by the Council, who made a grant of £300 for the purpose from the 1st April, 1937, to the 31st March, 1938.

Mastitis in Dairy Cattle.

Mastitis in dairy cattle has been especially studied at the Research Institute in Animal Pathology of the Royal Veterinary College over a period of years, and work on the same subject has been carried out since 1934 at the Hannah Institute, where it is under the direction of the Scottish Board of Research in Veterinary Science and its Mastitis Committee. The work on mastitis at the Royal Veterinary College has actively continued and has included further studies on streptococcal mastitis, and studies on the form of mastitis due to infection with staphylococcus, especially on the toxins produced by staphylococci of human and animal origin and their importance as causes of food poisoning. The commonest form of mastitis, which runs a chronic and gradually progressive course, is very widely prevalent[38]. Estimates of the frequency of its incidence vary very much according to the methods used for diagnosis. In one series of observations, out of 54 samples of Grade A

(TT) milk from 24 producers examined at the Royal Veterinary College, 42 contained the characteristic streptococci. Diagnosis is often made by examining the deposits microscopically for pus cells or by testing freshly drawn milk with dyes for its alkalinity, but these methods are relatively inaccurate and miss a number of early or slight cases, which are revealed by bacteriological examination. There are at least four kinds of streptococcus associated with different forms of mastitis[39, 40].

Streptococcus agalactiae is regarded as the cause of the commonest definitely infectious form of mastitis. It can be recognised by the appearance of the colonies on specially prepared blood agar plates, by the chemical changes which it produces in test liquid culture media and by its reactions with specific serum[41, 42]. Two other forms of mastitis, which are less common and much less infectious, are associated with other kinds of streptococcus. The milk from the above-mentioned common forms of mastitis is harmless to human beings. The occasional occurrence of severe epidemics of sore throat or scarlet fever in man acquired by drinking raw milk is caused by a type of *Streptococcus pyogenes* which has invaded and set up inflammation in the cow's udder and has probably been derived from contact with human sources of infection. The *Str. pyogenes* does not multiply in milk at ordinary atmospheric temperatures, so that it is unlikely to be present in milk in sufficient numbers to infect man unless it has already multiplied in the cow's udder[43].

Another form of mastitis which may be very acute and even fatal is the result of infection with staphylococcus, which may also cause less severe and more chronic forms of diseases, and may affect the udder of sheep, producing multiple abscesses. Different strains of staphylococcus have been under examination at the Royal Veterinary College, and the toxins which they produce have been studied in relation with those made by strains from other animals and from man[44]. Toxin inactivated by formalin is being used as a protective vaccine.

It is necessary to examine the milk from mastitis cases bacteriologically if control of the disease in a herd is to be successfully undertaken, in order that slight cases of infection may be detected and all sources of infection guarded against as early as possible. The essence of control is to prevent transmission by infected milk, which usually takes place through the hands of the milkers. This is best secured by attention to cleanliness, but especially by segregating the infected cows or simply milking them last. Since early diagnosis is so necessary the herd must be examined and the separate milks (preferably drawn from each quarter separately), cultured by suitable bacteriological technique, at first every month and at least every three months[45]. In some herds the form of mastitis due to *Streptococcus agalactiae* has been banished by the above methods, and in others great improvement has been effected. In order that the bacteriological examination should be made as often and as quickly as possible, improvements in the technique are being investigated at the Hannah Institute, where a study is also being made of the influence of nutrition on the course of the disease and of the possibility of preventing summer mastitis by the application of teat seals[46]. Treatment of early cases of this disease by injecting disinfectants such as acriflavine, etc., into the teat canals is being tried and some success has been obtained[47].

Examination of the records of the milk yield of cows infected with mastitis and contagious abortion has shown that either disease causes serious loss in the quantity, and that when both diseases are present the loss is still greater. In one herd in which 180 lactations were recorded in Ayrshires and 193 in Friesians the average reduction per lactation due to mastitis was 954 lb. and that due to mastitis and *Br. abortus* infection combined was 1,685 lb. The reduction due to mastitis was, on the average, 10·8 to 19·6 per cent. in different herds[48].

Towards the cost of the work on the diagnosis and control of mastitis in dairy cattle the Agricultural Research Council approved a grant to the Hannah Institute of £375 for the period from the 1st April, 1936, to the 31st March, 1938, the balance of the cost during the first year being met from private sources.

The Committee on Helminths of Economic Importance (Animals Section).

Towards the close of the period under review, this Committee presented a report on the work in progress in Great Britain on helminths of importance because of their occurrence in farm animals.

It is well known that certain parasitic worms are responsible for serious diseases in farm animals, and it is commonly believed that many other species, when present in large numbers, may be responsible for unthriftiness, loss of condition and death in all forms of stock.

The conditions existing in worm infestations differ so greatly from those of bacterial and virus infections that the modes of investigation which must be applied are quite different from those used by students of more ordinary infective diseases.

The primary difference is that there is no multiplication of individuals of the parasite within the body of the host; every adult worm found in an animal has gained entrance to it from outside, either by penetrating the skin, by being injected by an insect, or more commonly by being taken in through the mouth with the animal's food. This method of infection is associated with the elaborate life histories of many parasitic worms. All parasites produce large numbers of eggs, indeed in some cases fantastically great, and these eggs are usually enclosed in capsules or cases which may be extremely resistant to all agents, including poisons.

In many cases the larvae which arise from these eggs do not directly infect new individuals of the original host species, but enter into members of an entirely different species, a pond snail or an earthworm for example, within whose body multiplication of the parasite may take place by a non-sexual process. Only by the eating of the secondary host, or by some equivalent device, do such parasites again reach their original host.

In other cases amongst the nematodes (the round worms) the egg hatches into a larva, which by a process of ecdysis reaches the infective stage. Such infective larva may be capable of living for months, and may climb up blades of grass so as to increase the probability that they will be eaten by a member of the host species.

The first necessity of all helminthological work is an accurate discrimination of the species involved and the clear statement of diagnostic characters. This foundation has been completed (or nearly so) for the parasites of farm animals in Britain.

The next stage is the determination of the life history of each species. Here also, with a few exceptions, we have an adequate knowledge of the outline of the process. But we are still ignorant of many minor details; e.g. the time required for the production of the infective larva from the egg under varied conditions, the period for which infective larvae may survive in fields, in poultry houses, etc., the actual movements of the larvae and the details of their distribution on pastures. Research on such problems is in progress at Weybridge, Winches Farm, and elsewhere. Since the ultimate object of the researches with which the Council are concerned is the control of economically important disease producing worms, it is an obvious necessity to distinguish harmful from innocuous species. This discrimination is most difficult to secure. In such cases as the liver fluke of sheep there is no possible doubt; vast numbers of young sheep unquestionably die each year from the effects of this parasite.

Red worm of horses is also lethal. But the abundant nematodes of sheep are in a very different position. One (*Haemonchus*) was responsible for so serious a decline of sheep rearing on certain farms in South Africa that they became unsaleable. With the introduction of a simple and effective antihelminthic the value of these farms increased immensely. But the real status of *Ostertagia* and the Trichostrongyles which are more abundant in Britain is much more doubtful. The deaths of many sheep, and the poor condition of more are often attributed to these worms. But fat lambs may harbour very large numbers, and the Rowett investigations show that in a flock those sheep which show the greatest live weight increase may have the heaviest worm burden, simply because they have eaten more grass.

In the case of poultry, the Veterinary Laboratory at Weybridge fed chickens at weekly intervals with various numbers of eggs of Ascaridia and Capillaria. These chickens gained weight as rapidly as the uninfected controls. Thus, although many species of worms are suspected of pathogenicity, very few can be shown by controlled experiments to cause real damage to their hosts, at any rate if these are otherwise healthy and well fed.

The direct effect of the worms on their hosts requires much further investigation. The Animal Pathology Institute, Cambridge, carried out researches which showed, in confirmation of earlier work, that gut nematodes produce and pass out of their bodies substances which inhibit the action of proteoclastic enzymes, thus reducing the amounts of amino-acids available to the host.

The same institute is investigating the pathology of helminth infections, that is the reaction of the host. One special case of such reactions is perhaps of primary importance. It is generally observed that the worm burden of lambs in a flock is greater than that of sheep grazing with them, and that, as judged by counts of eggs in the faeces, the number of worms harboured by an individual lamb becomes smaller as it grows older, after a maximum is reached. The partial immunity so reached is at present unexplained. It may be due to the presence of immune bodies in the blood as is the acquired immunity to virus and bacterial diseases. This view is supported by a few competent workers for certain species of Trematodes and Nematodes. It is doubtful whether if true it could form the basis of preventive measures, but the possibility should be explored. It is possible that the greater resistance of old hosts to infection may be merely mechanical, depending on altered gut movements for example.

It has been claimed that the resistance of a host to infection can be lowered by malnutrition, either general inadequacy or a definite avitaminosis. The Rowett Institute is investigating this problem by administering small definite doses of a mixed culture of gut nematode larvae at regular intervals to a large number of worm-free lambs, which are kept at different levels of nutrition. The Institute of Agricultural Parasitology has done similar experiments with chicken infected with *Heterakis*, obtaining positive results.

It is evident that by far the best control measures would be those which reduce the chances of infection. In the case of the liver fluke of sheep, the conditions for such procedure are exceptionally favourable. The life history of the worm has long been known and it is stated that only a single species of water snail (*Limnaea truncatula*) can act as the essential intermediate host. In some parts of the country the population of this snail was very greatly lowered by the two dry summers of 1934 and 1935, and the total worm population of the area correspondingly reduced. Under these circumstances a survey of the distribution of the snail in definite areas followed by measures calculated to reduce the amount of re-infection of the snails and to lower their numbers is certain to yield information which will be of great value in designing measures for the control of this very serious pest in other areas. The Institute of Agricultural Parasitology is carrying out the survey of an area, which is the necessary preliminary stage of such an investigation.

In all ordinary cases control methods must be based on modifications of the methods of husbandry. It is evident that if a flock of sheep infected with a nematode be grazed on worm-free land this land will immediately be strewn with nematode eggs. These will not reach the infective stage for a period of the order of ten days: after that period re-infection of the sheep will begin, and if they be kept on the same ground will steadily become more and more rapid, apart from any resistance acquired by the sheep. If, however, the flock be moved on to clean ground, no re-infection can occur, and if the process be repeated indefinitely the flock may be expected ultimately to become worm free. The ground so grazed will be left with a population of infective worms, and it is necessary to discover for how long these may survive. The Institute of Agricultural Parasitology and the Veterinary Laboratory at Weybridge have made experiments to determine this point which show that some infective larvae may live half a year or longer.

If the period for which the sheep be kept on each plot be too long, or if they come back to a plot after too short an interval, very heavy infections may be built up, especially if the land be overstocked. The Institute of Agricultural Parasitology has demonstrated this fact by experiment. Thus, in principle, rightly designed rotational grazing should be able to clear a flock of nematode parasites. But in practice such a result can scarcely ever be economically possible; it involves too large areas of clean land, and a very heavy expenditure of labour. Even if incompletely carried out, however, it would reduce the average worm burden of a flock, little or much according to the density of stocking, the area available and the time which could elapse before the sheep came for the second time over the same ground. The old saying that " the sheep should never hear the church bells twice running in the same field " has a sound basis.

It it be impossible in practice by alterations in methods of husbandry to control worm infections the only alternative is to kill existing worms by poison, if possible before they enter the host, if not then whilst they are in the gut. The fact that infective larvae of nematodes crawl up grass leaves, and can only be eaten by a sheep when they have done so, suggests that they are freely exposed to attack by contact poisons. Such to be at all effective must be capable of penetrating the cuticle of the worms. This suggests that the nature of the cuticle and of its permeability should be investigated. Such physiological work is hindered by the difficulty of keeping nematodes in culture, not only in their free living but also in their parasitic stages. Such investigations are in progress and have reached a stage in which they are useful. But a wide fundamental investigation of nematode physiology has still to be carried out. Attempts to kill worm eggs and larvae on the ground have been made in poultry runs by the East of Scotland College of Agriculture in association with Edinburgh University. The effect of salting pasture on the infection of sheep has been investigated by the Rowett Institute and by Edinburgh.

It is highly improbable that a simple method, capable of application in ordinary farming practice, of killing eggs and larvae on pastures will be found, and direct treatment of infected hosts by anti-helminthics or vermifuges will always be necessary. Carbon tetrachloride is an effective agent against liver fluke, presumably because, when swallowed, it passes into the blood of the host, and is immediately carried to the liver, where the parasites are established. Round worms in the gut might be attacked in two different ways. Some of them feed on bacteria, influencing their hosts by abstracting food, producing anti-enzymes, and by mechanical damage to the gut wall. Others may in effect browse on the lining of the gut, whilst a further variety actually suck blood. The last group can obviously be attacked by injecting into the blood stream of the hosts substances which whilst harmless to it are toxic to the worms. But such intravenous drugs are unlikely to be effective against the other groups of parasitic worms, an attack on which can only be made by substances which are capable of penetrating the cuticle. If substances could be found which whilst fulfilling this requirement, were non-absorbable by the gut, the problem would be partly solved.

Little is known of the actual conditions existing within the gut of a ruminant, and it is clear that the complex stomach of these animals may influence greatly the speed and the certainty with which anti-helminthics administered by the mouth will reach the worms. In the absence of such fundamental knowledge of the physiology of the worms themselves, and of the ruminant gut, as would allow of planned experiments, the only possible procedure is to determine, so far as is possible, the toxicity of many substances to worms *in vitro,* then to discover the lethal dose of such substances to the host, and finally to try direct administration to heavily infected hosts. Such experiments are difficult to design and carry out. The only method of estimating the number of parasites harboured by an individual host is by counting the eggs of parasite, contained in the faeces of the host. It is not always possible to identify such eggs, although probably the larvae which escape from them are determinable. If this difficulty be overcome there still remains the fundamental uncertainty arising from the fact that an individual worm does not produce the same number of eggs per day under different nutritional and other conditions, or indeed throughout its life. In ordinary flocks the degree of infestation varies so enormously from sheep to sheep, that very large numbers must be used to secure statistically significant results from a comparison between treated and control series of hosts. Finally it is in practice usually exceedingly difficult to build up artificially a heavy infection in experimental animals, and the variation of the worm burden in them is usually great. These difficulties make it impossible to use sheep as the subjects of preliminary experiments, and the Institute of Agricultural Parasitology is working mainly with *Trichostrongylus retortiformis* in rabbits. This Institute, Weybridge and Wye[33] have investigated the action of a mixture of nicotine and copper sulphate, which is widely believed to be an effective anti-helminthic[33].

The following pages give a summary of the work in progress in the various institutions which fall within the purview of the Committee.

Institute of Agricultural Parasitology, London School of Hygiene and Tropical Medicine.—The research work at the Institute of Agricultural Parasitology covers investigations on the biology and control, therapeutics and pathology of internal parasites of farm stock, poultry, game and wild birds in so far as these are suspected reservoirs of infection, and of vermin.

(i) *Sheep and Goats.*—Studies on the effect of rotational grazing on the worm-burden in sheep and goats have been carried on for several years, and the results in succeeding years with different climatic conditions are being studied. Attempts to rear worm-free lambs on clean pastures have revealed the fact that rabbits are reservoir hosts of one of the parasites of sheep and goats.

Other investigations on the parasites of sheep and goats include:—(*a*) The possible danger of feeding hay from worm infested fields. (*b*) The survival of infection on pastures. (*c*) Observations on a microsporidian infecting nematode parasites. (*d*) Studies on the life-cycle, the migration in the host and longevity of *Fasciola hepatica,* the liver fluke worm, and also on the distribution of *Limnaea truncatula* and other possible intermediate hosts. A special grant has been made for this investigation from the funds at the disposal of the Agricultural Research Council, amounting to £867 for the period from the 1st October, 1936 to the 31st July, 1938.

(ii) *Dogs.*—Studies on tapeworm infestations in dogs leading to investigations into problems of helminth immunity.

(iii) *Horses.*—A preliminary survey of the worms which are of pathogenic importance in horses in Britain, and the application of ascertained biological facts to the routine of stud management.

(iv). *Pigs.*—Investigations on *Ascaris* in pigs have been carried out for a number of years, and infections of pathogenic importance have been obtained through feeding *Ascaris* eggs in small doses and repeated at intervals. Infections were found not to confer immunity against subsequent infections.

(v) *Poultry.*—It has been found that wild birds can act as important disseminators of gapeworms in poultry and that earthworms are important intermediate hosts.

Investigations on treatment, immunity and the influence of food deficiencies are also in progress.

A grant from the funds at the Council's disposal of £1,200 for the period from 1st August, 1936 to the 31st July, 1938, has enabled the work on anthelmintics to be considerably extended. This work involves the investigation of a wide range of chemical substances and has special reference to the problem of the control of helminthiasis in sheep.

Veterinary Laboratory, Ministry of Agriculture and Fisheries, Weybridge.

(i) *Sheep.*—Field investigations on parasitic gastritis in sheep have brought to light a number of important factors governing the increase of worms to a disease-producing number. The number of worms depends on, (*a*) the number of eggs produced by the parasite in the sheep and liberated on to the pasture in a viable condition; (*b*) the transmissibility of the infective larvae; and (*c*) the susceptibility of the sheep. These factors are influenced by climatic conditions and agricultural practice. Outbreaks of parasitic gastritis can occur as the result of residual infection on the land and also as the result of auto-infestation.

Numerous other important observations are being made on helminths in sheep, among which might be mentioned:—(*a*) the migration of worm larvae in the soil; (*b*) survival of infection in the soil; (*c*) the time taken for the development of helminthiasis under different farming conditions; (*d*) the effect of drought on outbreaks of disease; (*e*) field immunity experiments and treatment.

(ii) *Pigs*.—An attempt to show whether an invasion by *Bacillus* (*Salmonella*) *suipestifer* could be assisted by migrating *Ascaris* larvae proved negative.

(iii) *Poultry*.—Heavy infections with *Davainea proglottina* exercised no influence on the development of chickens. Similar results were obtained with moderate infections of *Capillaria* and of *Ascaridia*. It was found that land molluscs could act as intermediate hosts of the gapeworm. An instrument for the removal of gapeworms from the trachea of chickens was invented and has proved efficient in practice.

Institute of Animal Pathology, Cambridge.—Researches at Cambridge have been concentrated on the study of the physiology of the larval and adult stages of nematode parasites. Attempts have been made to cultivate the parasitic stages *in vitro* and it is concluded that further studies on the biophysics of the ecdyses and on the physiology of the infective larvae are necessary before this can be successfully accomplished. It was found that the second ecdysis depends on the permeability of the sheath, the osmotic pressures inside it, and on the movements of the larvae.

Observations have also been made on the seasonal variations of the species of worms in sheep, the lesions they cause in the host and the effect of urine on their pre-parasitic stages.

Rowett Research Institute, Aberdeen.—Researches at the Rowett Institute have been almost entirely concerned with parasites in sheep, and grants have been made from the funds at the disposal of the Council for this purpose, amounting to £502 for the period from the 1st October, 1935 to the 30th September, 1937.

The investigations have been carried out along the following lines:—(*a*) The influence of nutrition on the susceptibility of sheep to worm infestation. With the same chances of infestation, poorly fed sheep were found to retain more worms. (*b*) A survey of the worm infestation in sheep under different methods of sheep husbandry and studies on the correlation between worm-burden and live-weight increases. An extreme variability of infection between sheep in the same flock was observed. (*c*) Sheep pasture management in relation to the control of parasites by a system of progressive sectional grazing and by the salting of pastures has been investigated. (See also pp. 183-184.)

Poultry.—Preliminary investigations on the pathogenicity of poultry parasites have been commenced.

Zoology Department, University of Edinburgh.—Apart from some miscellaneous observations on the helminth parasites of sheep and pigs in the Border districts, the research work in Edinburgh has been chiefly confined to studies on the parasites of poultry. A survey of the worm infestations in Scottish poultry has been carried out and has shown that few of the species recorded from poultry are in any way common in Scotland. There also appears to be no correlation between intensity of infestation and certain diseases, such as fowl paralysis. Further studies on the worms in fowl paralysis birds from certain farms are in progress in collaboration with the Royal (Dick) Veterinary College. An examination of all dead birds from the Seafield Egg-Laying Test forms part of the routine work of the Department.

It has been shown by carefully controlled experiments that the chemicals commonly used by poultry farmers for treating infested poultry runs are quite ineffective against the parasitic nematodes of poultry. Investigations along these lines are being continued. In 1935-6 infested pens were placed at the disposal of the Department by the Edinburgh and East of Scotland College of Agriculture for these tests, and the Council made a small grant of £70 to the College to cover the cost of fencing and some additional houses.

Sheep Blowflies.

In the Council's last Report a note was included on the work which Dr. R. P. Hobson had begun since his transfer to the University College of North Wales, Bangor, from the London School of Hygiene and Tropical Medicine, where he had been studying the nutrition and growth of the larval stage of the sheep blowfly or maggot (*Lucilia sericata* Meig.). This work had been carried on partly in collaboration with the late Dr. Maldwyn Davies, of whose death in the middle of a distinguished career the Council learned with great regret. In Great Britain, in contrast to Australia, *Lucilia sericata* appears to be the only species of blowfly which attacks living sheep.

In August, 1935, the Council received from Professor R. G. White of the School of Agriculture, Bangor, proposals for continuing the investigations for a further period of three years. The main lines along which research was proceeding were to study the factors predisposing the sheep to susceptibility to "strike", to test both selected repellents and traps and poison baits, and to undertake field experiments and observations bearing on the susceptibility of different breeds and different individuals and on the value of dips and treatments. In the course of the investigations it had been established that the blowfly is attracted by a combination of some substance associated with the sheep itself (probably a volatile sweat constituent) and the products of putrefaction, for which certain chemical substitutes (the simplest being ammonium carbonate) are effective. They induce the blowfly to lay its eggs, but this is only the case when they are placed close to the skin of a live sheep. Other blowflies do not respond to these attractants. The knowledge thus gained of the factors which favour blowfly attack is valuable in connection with the testing of repellents in the field. It had further been ascertained that the eggs and larvae of *Lucilia sericata* are highly susceptible to desiccation, and that on healthy sheep skin the humidity must be over 90 per cent. for at least 14 hours (nine hours for the incubation of the eggs and five hours for larval activity) if full development of eggs and larvae is to take place. The humidity at the base of the wool is considered to be the main factor causing the susceptibility of a sheep to attack. The fleece near the skin is dry except in the region of the rump, which is often moist owing to soiling, and it is in this region that strike frequently occurs. It is also held that there is little doubt that the presence of moisture will lead to bacterial decomposition in the fleece and thus provide the conditions which stimulate the blowfly to lay its eggs.*

It was felt by those concerned with these investigations at Bangor that for the satisfactory application of the knowledge gained it was necessary to have at their disposal an experimental flock of 100 sheep, and accordingly application was made for a non-recurrent grant of £215 for the purchase of sheep and the erection of a dipping bath and pens as well as for a maintenance grant of £655, a sum which included Dr. Hobson's salary. It was expected that most of the expenditure on sheep would be recoverable.

The programme of investigations over the three-year period was planned to cover (1) fundamental researches on the factors constituting susceptibility, such as the humidity in the fleece of different breeds and the effects on such humidity of weather and of dips, the chemical nature of the substances attracting and repelling the blowfly, and the chemistry of the fleece; (2) tests of control measures (sheep dips, repellents, traps and poison baits, and materials lowering the humidity of the fleece); (3) field observations and experiments, concerned with the relation between wool type and discolouration (to which Australian workers attach importance) and susceptibility, inheritance of features which may be associated with susceptibility, the study of locality in relation to incidence of attack and large scale control measures; (4) entomological studies on the physiology of reproduction and oviposition and on the effects of dips and poisons on eggs, larvae and adults. It was urged that for fundamental research of so complex a character sheep of known history were essential and that experiments must be repeated in more than one year. In regard to studies on the chemistry of the fleece, the co-operation of the British Wool Research Association was assured.

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* (1) Maldwyn Davies, W. and Hobson R. P. — Sheep Blowfly Investigations: I. The Relationship of Humidity to Blowfly Attack. Ann. of Applied Biology, Vol. XXII, No. 2, pp. 279–293.

(2) Hobson, R. P. — Sheep Blowfly Investigations: II. Substances which induce *Lucilia sericata* MG. to oviposit on Sheep. Ann. of Applied Biology, Vol. XXII, No. 2, pp. 294–300.

The application was supported by the Ministry of Agriculture and Fisheries, who were prepared to exempt the experimental flock from compulsory dippings, subject to control of the movements of the sheep. The Council were well satisfied with the quality of the work done and with the excellent progress made in the investigations. They agreed that a grant not exceeding £960, including £215 for non-recurrent expenditure and provision for an increase in Dr. Hobson's salary and for a contribution towards his superannuation premium, should be made for the year beginning the 1st October, 1935, and they stated that, subject to funds being available and to the receipt of satisfactory reports, they would be prepared to consider favourably applications for grants during a further period of two years.

The application for the year beginning the 1st October, 1936, was accompanied by a further interim report. Under controlled laboratory conditions it was observed that gravid female flies were more attracted to products of putrefaction of meat than flies in other stages of development. One object was to attract maggot flies to traps away from sheep. It was shown that in test tubes containing cotton wool soaked with a dilute solution of indole females readily laid eggs. A suitable test of repellents was devised; this took the form of emulsifying the standard attractant (a solution of indole and ammonium carbonate) with different chemicals. Other investigations were concerned with the rate of reproduction of the blowfly; with the effect on blowflies of dipping materials designed to control sheep scab; with wool conditions akin to the Australian fleece rots which may provide attractive sites for oviposition by blowflies, and with the efficacy of dressings. Neither carbolic dressings nor glyceroboric mixtures, as used in Australia, were found to be satisfactory. A dressing is needed which will kill the maggots rapidly and yet will not aggravate the wound caused by the maggots. From a study of the development of the incubation and larval period on the sheep it appeared that there was a prolonged first instar period during which attack by a stomach poison other than arsenic might be possible. A comparative study of the effectiveness for purposes of trapping of the ammonium-indole method and the use of carrion was in progress.

The Council, after considering a report by Professor D. M. S. Watson on his visit to Bangor in January, 1936, recommended that a grant of £735 should be made available for the year beginning the 1st October, 1936.

During 1936-7 Dr. Hobson investigated in the laboratory the effect on sheep blowflies of a number of stomach poisons and found that rhodonates were extremely toxic. Dipping tests were made with some of these poisons. As it is essential that the skin surface of the sheep shall retain sufficient poison to kill the blowflies before they cause inflammation and subsequent exudation from the skin, Dr. Hobson favours a poison acting partly by contact and one which will mix with the wool grease and spread down to the skin as the wool grows. He is therefore testing organic oil-soluble compounds. Experiments with repellents had been begun too, as well as on dressings for wounds likely to prevent further strike. Investigations on the wool conditions associated with strike were also being continued in association with Dr. Duerden of the Wool Research Association.

In the course of researches on the physiology of reproduction of blowflies under the best nutritional conditions, it was observed that at a temperature of 37° C. eggs developed in two days, whereas development was not complete for 13 days at a temperature of 15·5° C. About one-half these times separated the period between the first and the second laying of eggs. The important discovery was made that if the eggs are to mature the female fly must have at least two feeds of meat, and this discovery leads Dr. Hobson to suggest that attack by blowflies might be alleviated if carrion and sources of carrion, such as rabbits, were destroyed and traps were also set for flies. In his work on trapping Dr. Hobson is co-operating with Dr. Thomas, who has succeeded the late Dr. Maldwyn

Davies as Adviser in Entomology at Bangor. It is believed that trapping with live sheep would be the ideal method, as only gravid females of *Lucilia sericata* would be attracted, but this method is not easy to adopt under farm conditions. Experiments with carrion baits are therefore being made. So far none of the chemical substances which cause the laying of eggs by blowflies in test tubes and, on occasion, when exposed in cages, have had this effect in the field.

Collaboration was maintained between Dr. Hobson and workers in the Natural History Department, University of Aberdeen, the North of Scotland College of Agriculture, and the Rowett Research Institute. For the continuation of the Scottish investigations under the direction of Professor James Ritchie the Council agreed that a grant of £54 for travelling expenses, chemicals and materials to be used in compounding dips and washes, and apparatus should be made available in the year beginning the 1st January, 1936.

The scheme of investigation which the Council had been aiding in the north of Scotland began during the season of 1933 and consisted of field studies of the flies in relation to their attacks on sheep, trapping experiments to determine the distribution of the flies, laboratory studies on development in relation to environmental conditions and the gathering of information regarding the incidence of strike by means of a questionnaire. Mr. F. N. Ratcliffe, who had taken part in the Australian investigations on this pest, was chiefly responsible for the field and laboratory work in the first years of the Scottish investigations; he received valuable entomological collaboration from Dr. Guy Morison, Advisory Officer in the Aberdeen and North of Scotland College of Agriculture, while Mr. W. Moore of the College staff gave special attention to dips and the technique of dipping or spraying. The staff of the Rowett Research Institute also took an important part in the investigations. A summary of the results of the 1933 investigations was given in the Council's last Report.

Professor Ritchie reported that in the spring of 1936 the work in progress at Bangor and Aberdeen was discussed thoroughly with Dr. R. P. Hobson and that agreement was reached in regard to the lines of research to be followed at the two centres. Dr. Guy Morison was able in 1936 to analyse the information gained during 1933-4 by the use of a series of standard traps as to the effect upon the distribution of blowflies of situation, weather and flock movements. The catch was highest in sheltered places exposed all day to the sun and lowest in a wood. The greatest numbers were caught in hot or warm weather, when there was no strong wind but some hours of sunshine. The presence of sheep and their movements definitely caused an increase in the number of flies trapped. The evidence regarding the association which flockmasters and shepherds believe to exist between rabbit warrens and the prevalence of blowflies was negative, but the trap in this case was in a shady site where sheep did not congregate much.

Of the 152,815 flies caught and examined not quite 4 per cent. were sheep blowflies; the earliest fly was caught in 1933 on the 7th June and the latest on the 3rd October, 1933. Females greatly outnumbered males and the number of flies was fairly closely associated with the number of cases of strike.

Further efforts were directed towards preparing a dipping fluid which would on the one hand soak the fleece thoroughly and adhere to the wool even in rain, and on the other would destroy eggs or maggots, prevent attack by the fly and disinfect and assist the healing of skin wounds. Mr. Moore found after somewhat extensive experiments that an oil emulsion dip prepared by him was more effective and less dangerous than water soluble arsenical dips, and could be made fairly cheaply. A satisfactory dressing for sores was also tested.

Mr. Moore also gave attention to methods for avoiding the fouling of the dip, which may result in the fleeces of sheep which are dipped last being made attractive to blowflies. An experimental cabinet in which sheep are sprayed under pressure was designed by Mr. Edminson and proved effective, but its general use would require official sanction.

Dr. D. Stewart MacLagan carried out laboratory experiments in a breeding chamber, in which temperature and humidity could be controlled, with the object of gaining more exact knowledge of the effect of weather on blowfly activity. He found that maximum flight activity was limited to a temperature of 85° F. and a relative humidity of 74 per cent. and that activity was much depressed by temperatures above 95° F. or below 80° F. and by humidities lower than 44 per cent. A critical factor governing activity is, however, the relation between a temperature and that immediately preceding it, and the age of the fly is also of importance. Temperatures above 84° F. and relative humidities below 74 per cent. shorten the life period, but are most favourable for egg production. Males can tolerate adverse conditions less well than females. Low temperatures, desiccation and overcrowding of larvae delay pupation.

The Committee on Fowl Paralysis and similar diseases and on Coccidiosis.

The extraordinary increase of the number of deaths amongst the pullets which were competitors in the many "laying trials" which was observed in 1929 and has continued from year to year until now was brought to the knowledge of the Council on its formation, and one of the first technical Committees to be appointed had as its field Fowl Paralysis and allied Diseases and Coccidiosis.

A critical review of the literature of Fowl Paralysis was prepared by Mr. (now Professor) T. Dalling and is to be published by the Imperial Bureau of Animal Health. At first there was considerable difference of opinion between the members of the Committee as to the symptoms and histological appearance which characterised the disease; some authorities held that only affections of the nerves were diagnostic, whilst others adopted much wider criteria, holding that certain changes in the liver, ovary or iris were equally characteristic of the same disease.

In order to resolve this conflict of opinion the Committee held a laboratory meeting at the Wellcome Research Institute in January, 1937, at which members demonstrated their own preparations and reached agreement on the limits of diagnosis.

Fowl Paralysis, as now defined, is a condition which cannot be diagnosed with certainty in the living bird; indeed in some cases there are no visible symptoms whatsoever, except perhaps some loss in weight. In the most typical cases the first change recognised is that there is lameness beginning suddenly with a limp, or a drooping wing, the condition developing rapidly until the bird is unable to stand or the wing is completely dropped. Although helpless the bird may still be capable of struggling and may show little loss of weight. In some cases, the iris may lose its normal orange colour becoming grey, but such a change is in no way diagnostic since it may arise from other circumstances. In extreme cases the pupil may become irregular in shape and fixed, and blindness may follow. But in many cases death in flocks in which fowl paralysis is common may occur suddenly with no premonitory symptoms.

On post-mortem examination of typical cases it is usually found that the nerves supplying the leg or wing are enlarged, sometimes very grossly, over a short part of their length. Microscopical examination of the enlargement shows that it is composed of a mass of cells quite foreign to the normal nerve. These infiltrating cells are of a very characteristic and recognisable type, and resemble immature lymphocytes.

What appear to be early stages in the formation of such tumours have very much the appearance of ordinary inflammations, but the fully developed structures which are associated with such changes of the tissue proper to the nerve as to produce the paralytic symptom are usually regarded as neoplasms.

The changes which may take place in the eyes of birds in fowl paralysis flocks are usually an iridocyclitis in which the iris becomes infiltrated with cells of exactly the same nature as those which form the nerve tumour in typical cases. And this infiltration may go so far as to destroy the muscles of the iris, and may ultimately invade the retina.

It is universally observed that tumours in the liver or ovary or elsewhere are very common in fowl paralysis flocks, and it is found that the cells of which they are composed are usually of precisely the same nature as those which produce the typical lesions of fowl paralysis. The Committee are agreed that such lymphomata are to be accepted as evidence of Fowl Paralysis.

The resemblance of the infiltrating cells of fowl paralysis to lymphocytes suggested that they might be actual blood corpuscles and that the disease might be diagnosed by examination of the blood. This has, however, proved to be impossible, and the origin of the cells is still in dispute.

The members of the Committee have made extensive surveys of the occurrence of the disease, which has been shown to be very widely distributed, and to occur in flocks kept under widely different conditions of management. It is believed that the condition most frequently occurs in birds between five and twelve months of age, but there is evidence that it may not exhibit itself until the bird is three or four years old.

Many members of the Committee have endeavoured to transmit fowl paralysis by the injection of suspensions of cells taken from the enlarged nerves of a case into " clean " fowls of various ages and by many different routes. In a small percentage of cases such injected birds develop the disease, but unfortunately in all the experiments some control birds injected with suspensions of normal tissues or even with a saline solution have also gone down with the disease, and sometimes even untreated controls have developed it. Thus these experiments have failed of their primary purpose. Attempts have also been made to transmit the disease by mere contact or by the administration of faeces; these have all given negative results.

Two series of breeding experiments, one of which was on a very large scale, have been carried out by members of the Committee and these have yielded very significant results. In each case it has proved possible to separate out strains in which there is a very high incidence of fowl paralysis from others in which very few birds die of that condition. Crosses made between cockerels of " resistant strains " and susceptible pullets and *vice versa,* and between birds of the same strain, have shown a significant difference in the incidence of fowl paralysis between the offspring of resistant pullets mated to resistant cocks, and all chicks produced by susceptible pullets, whatever cockerels they were mated to. Thus, there is a heritable factor involved in the occurrence of the diseases.

The experiments are, however, difficult to interpret because it is evident that the birds included in the " resistant " and " susceptible " stocks are not all alike; it is evident from inspection of the detailed pedigrees of the experiments that the progeny of individual birds may exhibit an extremely high incidence of fowl paralysis, although the original bird may itself have been perfectly healthy, and the progeny of their sisters may be resistant.

It is evident that this great individual variability may in part account for the unsatisfactory results of transmission experiments.

In two cases there is evidence that the death rate from fowl paralysis has fallen very considerably in flocks maintained for some years without introduction of new blood.

It was at one time often held that fowl paralysis was a condition depending on heavy parasitic infections, either with coccidia or with intestinal worms. Two of the Committee's members have now recorded the occurrence of typical cases of fowl paralysis in birds which have never at any time been infested either with coccidia or " worms ". It has also been shown that *Salmonella* infections are not responsible for the condition.

It has at various times been suggested that fowl paralysis might be a result of a vitamin deficiency and that it might be curable by feeding with lettuce or some other source of vitamins. The Committee remain unconvinced by such claims.

At the Molteno Institute Dr. H. P. Bayon has investigated a progressive anaemia of fowls and two other diseases which might have been related to fowl paralysis. Both are tumorous, one a leukaemia and the other a transmissible lymphoma, which can be distinguished histologically from the lymphomatous condition which is Fowl Paralysis.

The most important work now in progress under the control of the Committee arose from a very remarkable outbreak of fowl paralysis which occurred at the Rowett Institute, Aberdeen[49]. As the most simple interpretation of the facts of this case involved an infectious element of a kind not shown in any of the experiments carried out by the members of the Committee, it was clearly desirable to seize the opportunity presented by the event to test the hypothesis of infectivity.

In outline the most important experiment consisted in dividing a very large number of day old chicks derived from a stock whose entire history is known from 1928, and which during that time has never produced a single case of fowl paralysis, into two groups, one of which has been reared in the old houses in which fowl paralysis was very abundant in 1936, in association with older birds which were clinical cases, whilst the other moiety was reared in a house of similar size and character, newly erected and designed to secure the highest possible degree of isolation.

The faeces from these birds were regularly examined for coccidia, it being held that these parasites are so widely and easily distributed that the occurrence of their cysts in the droppings would give prompt notice of any breakdown of the isolation. This experiment is not yet concluded.

Thus, although the cause of fowl paralysis is still unknown, the work of the members of the Committee has elucidated very many facts about it which will facilitate the design of all further experiments devoted to its understanding and ultimately to its control.

In 1936 the Agricultural Research Council were informed that the valuable stock of birds that were maintained at the Wellcome Research Laboratories at Beckenham in connexion with the breeding experiments on the inheritance of suspectibility and resistance to fowl paralysis were in danger of dispersal. A conference was held by the Council with representatives of the Laboratories, of the Ministry of Agriculture and Fisheries and of the Scientific Poultry Breeders' Association in July, 1936. As a result it was agreed that the flocks in question should be maintained at Beckenham, or, if that proved impracticable, elsewhere, until such time as the Agricultural Research Council could take them over at their proposed Field Station. Arrangements were eventually made to keep them on at Beckenham, and their transference to the Council's Field Station at Compton will shortly be effected.

For the major experiments on the means of spread of fowl paralysis at the Rowett Research Institute the Council approved special research grants amounting to £750 capital and £2,340 maintenance for the year from the 1st April, 1937. An additional grant was approved to the Royal (Dick) Veterinary College, Edinburgh, of £275 for the same period to provide assistance to Mr. J. E. Wilson so as to enable him to co-operate in the work by the examination of all the birds that died during the experiment. A small grant of £25 was made at the same time to the Institute of Animal Genetics, Edinburgh, to facilitate the supply to the Rowett Institute of birds of known history and freedom from fowl paralysis from Dr. Greenwood's stock.

Other grants made on the recommendation of the Committee included £240 for the period from the 1st October, 1935, to the 30th September, 1937, towards the cost of Mr. J. E. Wilson's survey of the incidence of fowl paralysis in Scotland, and sums of £50 to Manchester University and £160 to the Molteno Institute, Cambridge, for laboratory and experimental work on the disease at these centres for the year from the 1st October, 1935.

The Agricultural Research Council, on the advice of the Committee, provided for the appointment of a special research officer for the investigation of coccidiosis, but owing to the difficulty of finding a suitable worker it is only within the last few months that Mr. C. Horton Smith has been appointed and work on this subject has been undertaken by him at the Veterinary Laboratory of the Ministry of Agriculture and Fisheries at Weybridge.

The Committee on Equine Research.

In the autumn of 1935, the Racecourse Betting Control Board approached the Ministry of Agriculture and Fisheries intimating their desire to give financial support, from funds derived from the Totalisator, to research on certain diseases of horses, especially those affecting thoroughbreds. The Board's proposals were discussed at a conference convened by the Council in October, 1935, with representatives of the Ministry and the Racecourse Betting Control Board. At this conference the Board's representatives expressed the wish to have the advice of the Council on the subjects on which it would be advisable to carry out research and on how best to allocate the money at their disposal. At a later conference attended by veterinary research workers and practitioners, it was decided, with the concurrence of the two Agricultural Departments, to propose that the money provided by the Board should be used for work on three problems which were causing concern to those connected with the management of racehorses, namely, epizootic coughing, scouring in foals and sterility.

Following these conferences, the Council set up a Committee on Equine Research to co-ordinate and supervise existing and plan new research work on diseases and disorders of horses. This Committee was appointed in consultation with the Racecourse Betting Control Board, the Thoroughbred Breeders' Association and the Army Veterinary Service. Definite plans for work on the three selected problems were considered.

Epizootic coughing attacks farm horses as well as thoroughbred horses, but the latter are the more seriously affected. The disease is infectious and, according to German workers, is due primarily to a virus infection with a bacterial infection superimposed, of a character closely allied to influenza. Although it results in little or no mortality its infectious nature, and the risk of secondary infections being set up if horses suffering from it are worked, often means that the whole of the horses in a particular stable are inactive. For this reason the disease ranks high in the list of those of economic importance. A serious outbreak of epizootic coughing occurred in 1935, among racing thoroughbreds, hunters and army horses, and caused widespread interference with work and considerable losses. A grant of £100 was approved for work on this disease out of the funds provided by the Racecourse Betting Control Board and, with the permission of the Medical Research Council, a preliminary investigation with small laboratory animals was arranged at the National Institute for Medical Research to be carried out under the direction of Sir Patrick Laidlaw. The results to date of this preliminary investigation are encouraging, but difficulty in obtaining sufficient clinical material is hampering the work. Experiments with ferrets by means of swabs taken from horses suffering from what was diagnosed at the time as epizootic coughing, have given indications that a virus element is present, one of the ferrets when inoculated having shown a striking diphasic temperature response reminiscent of influenza; on passage to other ferrets, however, the infectivity disappeared.

Scouring in foals, the second of the disorders on which it was decided to begin preliminary investigations, develops in two forms, one of which occurs soon after birth, and the other towards weaning time. The epizootic diarrhoea, the main symptom of the disease, may spread rapidly, and when one case occurs, every foal born afterwards in the same premises runs the risk of becoming infected. The incidence of mortality from the disease may be as high as 50 per cent. A sum of £50 has been set aside from funds provided by the Racecourse Betting Control Board for the purpose of a preliminary investigation of this disease at the Institute of Animal Pathology, Cambridge. It is not possible to record much progress as yet owing again to lack of the necessary clinical material.

The investigation of sterility and fertility in the horse from the physiological aspect is being conducted at the Institute of Animal Nutrition, Cambridge, under the direction of Dr. J. Hammond[50]. The cost of the investigation to date has been met by a grant of £350 from the Council out of the funds provided by the Racecourse Betting Control Board and a grant of £200 made by the Thoroughbred Breeders' Association. Mr. F. T. Day, M.R.C.V.S., was appointed on the 1st January, 1937, to assist Dr. Hammond in the investigation, by collecting observations and data, and testing out various means of diagnosing pregnancy on which there is a lack of information. Mr. Day's work has included the examination and treatment of barren mares; the examination of normal mares after foaling and of maiden mares; pregnancy diagnosis; and the examination of stallions suspected of low fertility. Professor W. C. Miller of the Royal Veterinary College, London, has assisted in the biological work in connection with pregnancy diagnosis. Up to the end of September, 1937, a total of 64 mares, barren for two years or more, had been examined. In the majority of these mares there was no apparent cause for their not breeding, but the others showed various pathological symptoms or gave positive cultures of pathogenic bacteria. Among the treatments tried were rupturing ovarian cysts, injections of (anterior pituitary) hormones and artificial insemination. A good number of the mares which were treated have since been covered, but it is not yet possible to record results. Several of them, however, appear to be in foal. Examinations of the sperm of seven stallions suspected of low fertility have also been made. Of these seven, four were thoroughbred horses and three heavy draught horses. In several of the cases the spermatozoa examined were either dead or few in number, and hormone treatment and high protein feeding is being tried on these animals.

The past year's work has shown clearly the difficulties of diagnosing and treating mares and horses at studs with which the investigator is not directly in contact, and the Thoroughbred Breeders' Association, who will in future be paying entirely for the cost of this investigation, have decided to establish out of their own funds a " Field Hospital " to which barren mares and infertile horses may be sent for diagnosis, observation and treatment. It is anticipated that the hospital will eventually become self-supporting. The Council have agreed that the establishment of such a hospital is eminently desirable and have accepted the invitation for the Council's Equine Research Committee to be represented on the scientific Committee which is being set up by the Thoroughbred Breeder's Association to supervise the research at the hospital.

A certain amount of research on sterility in the horse has also been carried out at the Institute of Animal Pathology, Cambridge, on material supplied by Mr. Day. In this way, a knowledge of the commoner types of micro-organisms present in the genital tract of mares has been obtained. With financial assistance from the Racecourse Betting Control Board, it is now proposed to extend the research at the Institute into the pathological aspects of this condition.

In addition to the investigations referred to in the preceding paragraphs, the Committee on Equine Research are supervising an investigation of disabling diseases of horses which is being continued at the Royal (Dick) Veterinary College, Edinburgh,[51] with the aid of a grant of £1,075 of which £625 has been found from the funds provided by the Racecourse Betting Control Board. This investigation, which is being carried out under the direction of Professor W. M. Mitchell and Professor R. G. Linton, was referred to in the last Report of the Council. During the period under review the work at the College has included the examination, histologically and otherwise, of the material which has been collected. The condition known as "navicular disease" is receiving particular attention. As a correlated piece of research, investigations into the mineral content of the food of horses and the liver reserves of vitamin A have been made at the Royal (Dick) College. Work in the Philippines has shown that the most serious disabling disorders of horses could be related to calcium and phosphorus deficiencies, which tends to indicate that rheumatic disorders of the type in question may be experimentally induced by diet deficiency. The result of the investigation on vitamin A liver reserves will be published shortly. Thirty Shetland ponies have been purchased for the experiments on diet deficiencies involved in these investigations.

Other work on osteodystrophic disorders of horses, for which it was found that the expenditure of additional money would not be required in the early stages, is to be conducted as and when opportunity offers, at the Ministry of Agriculture and

Fisheries Veterinary Laboratory, Weybridge, where Dr. H. H. Green[52] is collaborating with the Royal Army Veterinary School, Aldershot. There is at Aldershot radiographic apparatus specially designed for the horse, and it is proposed to conduct experiments combining the physiological aspect of these disorders with radiological work. A conference was convened by the Council in May, 1937, to secure co-ordination between the workers on these disorders.

The Council's Committee on Equine Research have also had under consideration the need for research on the condition commonly known as " heel-bug " in horses, which was reported to be particularly acute in 1936. A conference was convened by the Council in September, 1937, which was attended by veterinary surgeons and workers engaged on research on diseases of horses. A questionnaire was drawn up and has been addressed to trainers of racehorses, and to members of societies concerned with hunters and other thoroughbred horses; the replies will be considered at a further meeting of the conference before suggestions are put forward regarding the research to be undertaken. The Racecourse Betting Control Board have contributed a sum of £75 for a preliminary survey of the disease.

Reference was made in the first Report of the Council to the investigation of grass sickness in horses which had for some years been carried out under the direction of Dr. J. Russell Greig at the Moredun Institute of the Animal Diseases Research Association. There was a serious outbreak of the disease in 1913, but from that time until 1936 only sporadic cases have been recorded. In the summer of 1936, however, there was a devastating outbreak causing the death of some 1,500 horses in Scotland alone. Following this severe epidemic the work in progress at the Moredun Institute in the search for a causative bacterial toxin was extended[53]. The Development Commissioners and the Treasury, on the recommendation of the Council and the Department of Agriculture for Scotland, agreed to an appropriation from the Development Fund of such sum not exceeding £3,200 as, after taking into account any funds provided from other sources, might be required by the Moredun Institute to meet the cost of this extended work during the financial year from the 1st April, 1937. From the Racecourse Betting Control Board a sum of £1,000 has been provided to date for the same purpose, of which £800 was provided for special equipment and £200 towards the cost of the investigations.

The most recent work of the Moredun Institute on this disease has taken the form of a vaccination experiment. During the field investigation carried out in 1933, a search was made for the presence of bacterial toxins in affected animals. It was found that the toxin of *B.* (*Clostridium*) *welchii* type D occurred in a small proportion of acute cases. The same toxin was detected in a proportion of acute cases examined in 1934, 1935 and 1936. It was thought desirable to test out the significance of these findings on a large scale. In controlled field experiments with over 2,000 horses, 938 were vaccinated with a formalised culture of *B. welchii* type D, the vaccine having been selected after 11 preparations had been tested in horses, rabbits and guinea-pigs. The result of the experiment showed that immunisation against *B. welchii* toxin type D does not afford protection against grass sickness.

It is proposed to review again the programme of work at the Institute and elsewhere on this disease. It is also proposed to publish a full and comprehensive account of the work so far undertaken at the Moredun Institute, to include information on the history of the disease.

Although grass sickness in its early days was essentially a Scottish problem there have been, since about 1915, sporadic outbreaks in England and Wales. The Ministry of Agriculture and Fisheries has collected all the available data on these cases, which have occurred mostly in the North of England, but latterly also in Wales and the Southern Counties. Details have also been obtained of outbreaks among army horses, particulars of which were carefully kept by the Army authorities.

Foot and Mouth Disease.

In the first Report of the Council an account was given of a review undertaken in 1933, by a Sub-Committee of the Animal Diseases and Animal Nutrition Committees, of the work conducted since 1924 under the direction of the Foot-and-Mouth Disease Research Committee of the Ministry of Agriculture and Fisheries. The Sub-Committee reviewed the progress of the research work as set forth in the four Progress Reports of the Ministry's Committee and, besides a general recommendation in favour of the continuation of the investigations upon the foot-and-mouth disease virus, implying the continuance of the Pirbright Isolation Station on a long-term basis, the Sub-Committee made recommendations on certain aspects of the future work to be undertaken, and on the best organisation of the Pirbright Station to cope with it. Since that review, the Council have each year been consulted by the Development Commissioners upon the annual application for grant aid from the Development

Fund for the work of the Foot-and-Mouth Disease Research Committee. At a meeting of the Animal Diseases and Animal Nutrition Committees in April, 1936, when the application in respect of the financial year 1936-7 was being considered, the Committees decided that it would be advantageous if a further review of the position of research on foot-and-mouth disease were carried out. For the purposes of this review it was found necessary to defer deliberations for a year until the Fifth Progress Report of the Research Committee was available. This Report[54], covered the results of investigations during the five year period to the 30th September, 1935; the results of the most recent work, however, were not available in published form at the date of the Sub-Committee's review in April, 1937, and were obtained by conference with those in charge of the investigations.

The most important results which have emerged since the review of the Sub-Committee in 1933 are summarised below in the briefest form.

The work of Galloway, Elford and others at the National Institute for Medical Research on the physical character of the virus has made it possible to purify it to a high degree and to concentrate it by filtration and by washing. The filtration technique has enabled the virus of foot-and-mouth disease to be distinguished accurately from the viruses of vesicular stomatitis in horses and vesicular exanthema in swine. It has become evident that the virus is considerably more complex than was even realised before, and less stable. Of 88 strains received from outbreaks in this country during the period covered by the Fifth Report it has been found that, when tested on guinea-pigs, 51 behaved as type O, 22 as type A, 2 as type C, and that 13 could not be assigned with certainty to any of these types. Moreover it has become clear, as has been found with other animal viruses, that the transfer of the virus from one species to another (e.g., from guinea-pigs to cattle or *vice versa*) may cause a change in the behaviour of the virus, which apparently only becomes adapted to a different species of animal after passage through a number of individuals. A change in " type " appeared occasionally to occur during passage of the O type through guinea-pigs at Pirbright, but although the stock O type has been passaged in cattle continuously since 1928 there is no indication of a change of the virus in the course of passage through cattle. It is considered possible that some strains vary in their antigenic composition, while others remain more stable.

In the study of immunity, work with large animals has been developed. Considering the highly infectious nature of the disease and its complex character, very few cases of accidental infection have occurred within the isolation area. The average rate of such occurrences has been once in 18 months, and it is believed that three of the last four cases can probably be attributed to air-borne transmission spread by strong and persistent winds. The effect upon the pace at which the investigations can be pursued of even so relatively infrequent breakdowns has been serious, and justifies beyond a doubt all reasonable expenditure upon additional precautions. From the point of view of the prospects of inducing immunisation artificially it is encouraging to learn that in cattle, as distinct from pigs, a strong resistance to the disease over a long period is established by a natural attack.

In Germany a polyvalent hyperimmune serum has been used alone or in conjunction with an inoculation of living virus to protect animals in contact with cases of natural infection. On farms in an area surrounding a locality suffering from an epidemic, " ring inoculation " of this type is practised in an effort to limit the spread of the disease. The serum is also given to cattle consigned to shows or markets. Some success is claimed for this preventive treatment on the Continent, but experimental tests of such sera at Pirbright have proved to be disappointing.

There have been two main obstacles to success in vaccine production, which is perhaps the crucial section of the Pirbright experiments; the multiplicity and apparent instability of the virus strains and the difficulty of obtaining virus in sufficient quantity. Because of the first of these two obstacles the alternatives are to use a composite vaccine containing all types, or to select one or two sufficiently representative types. Galloway's filtration experiments give hope of the possibility of obtaining a highly concentrated virus. In order to increase the supplies of virus, attempts to propagate it in tissue cultures and in eggs, or to concentrate it by absorption have been made, but not so far with practical results.

The most careful attention has been given to the study of the means by which the disease may be brought into the country and spread from one area to another. Certain accidental breakdowns in the arrangements for isolation between different units at Pirbright, to which reference has been made, point to the possibility of the disease being carried in dust and other materials by strong and persistent winds blowing from one quarter. Little direct evidence has been found in this country for the existence of carriers among cattle. While much information has been gathered, and in suitable cases has been used as the basis of regulative measures, regarding mechanical carriers, such as meat, bones, hay and straw, and observations have been made on the resistance of the virus to heat (in relation to milk drying and the cooking of animal organs) and of the effect upon the virus of light, the source of a considerable number of outbreaks of the disease remains unknown. A survey by the Oxford Bureau of Animal Population of small wild animals living in an infected area, through which it was thought that diseases might be spread, has been somewhat hampered by the restrictions necessarily imposed in such an area and the immediate slaughter of infected cattle. The discovery that a hedgehog sent to Pirbright by one of the Ministry's Inspectorate was naturally infected has again suggested this animal as a possible reservoir of infection. The hedgehog has proved to be a valuable animal for experimental use. It is very susceptible to the disease and, unlike the guinea-pig but like cattle, can spread the disease by contact, *and through the breath,* both to other hedgehogs and also to cattle. There seems every reason to believe that, given more suitable accommodation, the hedgehog can be prevented from hibernating, an important matter, since during hibernation the disease becomes latent. More intensive study of the disease in hedgehogs should give very valuable results. It is to be hoped that these animals may be induced to breed in captivity, as the vole has been by the Bureau of Animal Population; captured wild animals are always difficult for experiment.

Studies on the rat indicate that well-fed and well-grown animals take the disease more readily than those that are undernourished. The probability is that very old animals are less susceptible than those which are growing rapidly; very young animals have also a lesser susceptibility than those which are approaching maturity. This observation is confirmed by experiments with cattle, guinea-pigs and hedgehogs.

These results give sufficient indication that since the last review of these investigations by the Agricultural Research Council, further knowledge of importance in the understanding of the disease, which cannot fail to be of value in devising administrative measures for its control, has been gained as the result of much patient, well-directed and laborious research. The main object to which the researches are now being directed is, however, the preparation of a satisfactory immunising agent for cattle, and the discovery that the virus is even more complex and apparently less stable than was believed to be the case compels a re-examination of the prospects of success.

In the report of the earlier reviewing Sub-Committee the opinion was expressed that while there was no evidence to justify the conclusion that the studies in immunisation at Pirbright envisaged by the Research Committee would " within a short time " result in practical measures being devised, which would make an extensive modification of the slaughter policy possible, the indications were such as to justify a reasonable hope that measures might be devised at a later " but not necessarily remote stage of the enquiry ". The potential saving in expense and the possible protection of valuable pedigree stock, would far outweigh the cost of the enquiry, even if it were continued over a long period of years; whereas to stop the investigations at the stage then reached would mean that much of the expenditure already incurred would have been unfruitful. Should the study of foot-and-mouth disease infection reach a point at which it was felt that all necessary knowledge of it had been gained, there was every reason to suppose that the Station would be most valuable for the study of some other infectious and contagious disease of importance to agriculture.

These views were endorsed by the more recent Sub-Committee who considered that investigations at this Station should be planned on a long term or semi-permanent basis, so that those members of the staff who have gained experience of the technique of virus research may eventually turn their attention to some other epizootic disease.

The re-examination of the work, in the light of the Fifth Report and of discussions with the Chairman of the Research Committee and the Director of Veterinary Research, has led the Council to the definite conclusion that the programme is sufficiently wide in scope to cover all those aspects of the disease and of the causal organism which, so far as can be judged, are likely to assist in tracing the source of outbreaks, in bringing outbreaks under control, and eventually in protecting cattle against serious infection. The attack has been planned as it should be, on a wide front, and full use has been made of the staff and facilities available. Progress has been slow, but within the limits of the available facilities and organisation, satisfactory. The complex character of the problems under examination, due to the nature of the virus, its high degree of infectivity and the consequent precautions essential to prevent its spread from one group of animals to another, make rapid progress in any circumstances extremely unlikely, and progress has been unavoidably delayed by essential alterations to the compounds at Pirbright.

Immunity experiments on large animals have not yet been made on an adequate scale to enable an answer to be given to the question whether a mixed vaccine can be found effective against a sufficient number of virus types, but the possibility of creating carriers by immunisation is one that must be faced. The difficulty of obtaining the virus in sufficient quantities for vaccine preparation has still to be overcome, though the recent success achieved by Galloway and his colleagues in purifying and concentrating the virus may well prove to be of great importance. It is further to be hoped that the present experiments in immunising pigs with vaccines made from material from hedgehogs, guinea-pigs and pigs may simplify the problem.

The cost of continuing research upon the disease on the basis of the programme envisaged is bound to be heavy, but assuming that a vaccine could be made in quantity which would give an immunity to cattle against the most prevalent types of virus found in this and in other countries, it should then be possible to avoid, or at least to limit the slaughter of pedigree or other valuable herds during the course of an epidemic in this country. Moreover a powerful weapon would be placed in the hands of the administrative authorities in negotiating with foreign countries in regard to the conditions governing the importation of animals and meat.

Thus, on economic grounds, both in regard to foot-and-mouth disease and to the several other virus diseases causing heavy losses the reviewing Sub-Committee did not doubt, and the Council take the same view, that the work at the Pirbright Station should be continued and developed.

Recommendations have been made for the further structural improvement in the Station; for the ensuring of adequate supplies of small animals for experimental purposes both of guinea-pigs and, if success attends the attempt to breed them in captivity, and to control their hibernation, of hedgehogs; for the re-organisation of the immediate direction of the research; and for the stabilisation of the position of the research staff itself.

Assuming that these measures are taken, the Council are satisfied that the hopes of producing an immunising vaccine are, in spite of the greater instability of the virus now revealed, much the same as those which were expressed four years ago.

There can be no certainty of success, but the attempt to reduce the great losses which this disease causes to stockowners in many countries is worth making.

MISCELLANEOUS SPECIAL RESEARCHES.

Sterility in Cows.

In 1935, proposals were submitted to the Council jointly by Professor J. B. Buxton and Dr. J. Hammond for an investigation of the problems of sterility in dairy cows to be carried out by a bacteriologist working at the Institute of Animal Pathology at Cambridge in co-operation with Dr. Hammond at the Institute of Animal Nutrition. It was reported that " sterility " was responsible for almost half the wastage due to the disposal of cows from dairy herds. Some aspects of the problem were already under study in Dr. Hammond's Department at the Animal Nutrition Institute but it was considered desirable to extend the enquiry into the causes of sterility by work of a bacteriological character.

The Agricultural Research Council in consultation with the Ministry of Agriculture and Fisheries made a grant from the funds at their disposal of £900 for the academic year 1936-7. Under this grant Mr. J. G. Murray was appointed to work at the Institute of Animal Pathology under the joint supervision of Professor Buxton and Dr. Hammond. The Council's Animal Diseases and Animal Nutrition and Breeding Committees attached considerable importance to the conduct of the inquiry on as wide a basis as possible so as to obtain as complete a knowledge as might be found to be practicable of the various factors involved in the causation of sterility.

Mr. Murray has carried out a bacteriological examination of specimens (e.g., foetuses) and of discharges from herds in which there is a history of sterility, in comparison with a study of the genital organs of normal cows obtained from abattoirs. No single pathogenic organism was found to be common to all the 15 herds showing sterility that were examined: in one case an organism apparently of the *Pasteurella* group was obtained and in another the protozoal parasite *Trichomonas foetus*. In some of the herds there was evidence that the sterility was not due to bacterial causes. More recently Mr. Murray has concentrated on the bacteriological examination of the cervix uteri and adjoining parts and has undertaken a study of the hydrogen-ion concentration of the secretions from these areas.

Included in the grant was a provision of £200 for compensation to owners, none of which was required. Arrangements have been made for carrying on the work during the current academic year.

Survey of Mortality among Calves.

The Council approved grants of £300 per annum for each of the two academic years 1935-6 and 1936-7 in aid of a statistical investigation into the mortality among calves in England and Wales to be carried out under the supervision of Professor Minett at the Research Institute in Animal Pathology of the Royal Veterinary College, Camden Town. Arrangements were made for the collection of data through Milk Recording Societies from over 300 farms in all parts of the country, covering more than 11,000 cows. The records between January and September, 1936, showed a mortality of 5·3 among all calves born alive (6,463), in sharp contrast to a mortality reported from a similar smaller scale inquiry carried out by Jordan in Ayrshire in 1931, when the mortality reached approximately 20 per cent. Some further data from 20 herds covering over 1,750 cows were obtained by Professor Minett direct from the owners during the same period as that covered by the reports from the Milk Recording Societies and these showed a loss of 7·9 per cent.

The Council sanctioned in 1936 a grant of £50 to the Hannah Dairy Research Institute to enable Dr. J. Wilkie, who was temporarily attached to the Institute, to collect data about calf losses in Scotland. It was considered that the information would form a valuable supplement to Professor Minett's survey of calf losses in England and Wales. The grant was subsequently increased to £125 so that Dr. Wilkie could carry it on up to the end of 1937. Professor Minett has kept in close touch with Dr. Wilkie in this inquiry.

MISCELLANEOUS INVESTIGATIONS ON ANIMAL DISEASES AT THE RESEARCH INSTITUTES.

Institute of Animal Pathology, Cambridge.

Studies on lactation tetany in cows are in progress, involving a botanical and chemical examination of the pastures in areas where this disease is prevalent, a study of the effects of feeding manganese to lactating animals, and blood analyses of the cattle from a herd in which a condition resembling lactation tetany occurs. Pastures where lactation tetany occurs always have a high manganese content. Work is in progress with sheep, on the pathology of swayback, but the cause of this disease is still obscure. No new facts have been obtained to indicate that the disease is due to a virus or bacterial infection. The identity of swayback with a disease of lambs in Australia has been established. Studies of the degeneration of the spinal cord and of the biochemistry of the blood in swayback are also in progress. A study of the biochemistry of pregnancy toxaemia in ewes has also been commenced. Progress has been made in the investigation of enzootic pneumonia in sheep, two strains of a *Pasteurella*-like organism having been isolated with regularity from a large number of affected lungs. A preliminary investigation of a " pox-like " or variola condition in young pigs has shown that this disease is more widespread than was suspected and may be responsible for fairly serious losses. In protozoology, studies of *Trichomonas,* coccidiosis and other pathogenic forms are in progress, while in helminthology several worms parasitic to livestock, especially sheep, are under investigation. Attempts to cultivate coccidia in tissue culture and an artificial media are being made. The behaviour of parasitic nematodes in artificial media of known composition is under observation. A wide investigation of the classification and histogenesis of tumours of animal origin on very extensive material from various sources is being undertaken.

Research Institute in Animal Pathology, Royal Veterinary College.

The major research work at this Institute has already been discussed in preceding pages. Research on the diseases of young calves was commenced in 1935 and it was in connexion with this investigation that the desirability of obtaining data regarding mortality amongst calves referred to elsewhere became apparent. Bacteriological examinations have been made of a considerable number of calves dying within the first three months after birth. In cases of scour 110 strains of *Bacterium coli* have been examined and classified. Studies have also been carried out on strains of *Corynebacterium pyogenes* isolated chiefly from cases of pneumonia in calves and from ovine metritis. Particular attention has been paid to the toxin produced by this organism. Helminthological investigations include studies on the life-cycle of members of the tape-worm family Anoplocephalidae, with special reference to the behaviour of the eggs under different physical and chemical conditions, and studies of the bionomics of the eggs and third (infective) larval stage of nematode parasites of the stomach and intestine of sheep.

Research Institute of the Animal Diseases Research Association, Moredun.

Some evidence has been obtained that white scour in calves can be reduced by the ingestion of vitamin A and an investigation of the percentage of this substance found in the colostrum of cows has been undertaken in order to test the possibility that a deficiency in vitamin A in the colostrum may be of significance as a cause of the disease. Controlled field experiments have also been designed to determine this question. A survey of the geographical distribution of lactation tetany in cows in Scotland has been undertaken in connexion with the previously ascertained fact that there is always a fall in the blood magnesium in cases of the disease. This inquiry is linked with research of a fundamental nature on magnesium metabolism. The work on "pine" in sheep is referred to in the previous section of this Report (p. 187), and most of the major investigations at Moredun are described earlier in this chapter.

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VIII.—DAIRY RESEARCH

In the last Report of the Council it was stated that Sub-Committees of the Council had visited the National Institute for Research in Dairying at Shinfield, near Reading, and the Hannah Dairy Research Institute and the Dairying Departments of the West of Scotland Agricultural College, both near Ayr. It was also explained that the Council had requested their Dairying Committee to prepare a general survey of dairying research in progress in Great Britain, and that the Committee were then completing their enquiries in preparation for their report to the Council.

These enquiries were finished in July, 1937. They were related, both to more recent information regarding the policy and work of the Institutes referred to above, and to work in the field of dairying being carried out by the Division of Bacteriology and Immunology of the London School of Hygiene and Tropical Medicine and in the laboratories of United Dairies, Ltd. Late in 1935 the Council were requested by the Development Commissioners to include in their review of dairy research an examination of the work of the ten dairy bacteriologists who are attached to different advisory centres throughout England and Wales. The Dairying Committee conferred with all these bacteriologists and also with the two officers who are concerned with advisory and investigational work in dairy bacteriology in Scotland. A full report by the Dairying Committee was presented to the Council in July, 1937. The Council decided that a revised edition of the report, suitably amended for general reading, should, subject to consultation with the Agricultural Departments, be prepared for publication in the Council's Special Series of Reports. It was thought that the report might be of particular interest and value to County Agricultural staffs, Agricultural Societies, etc. The revised edition of the report has now been published.*

The National Institute for Research in Dairying, Reading.

The Institute has suffered for a long time from inadequate room. This need for improved accommodation and research facilities is now in process of being met. A detailed scheme for new buildings drawn up by a Committee specially appointed by the Board of the Institute provided for new laboratories in a two-storied building to form a third side of a quadrangle, the rebuilding on its present site of the Machinery Shop and Testing House in order to meet the requirements of the testing of dairy machinery under the Agricultural Machinery Testing Scheme of the Ministry of Agriculture and Fisheries, the construction of experimental piggeries and a goat house to replace the existing piggeries, which were in a dilapidated condition, the building of a new house for the smaller experimental animals, and alterations to the existing sewage disposal plant, which failed to meet the requirements of the Local Authority. The Dairying Committee, after examining the scheme in detail, considered that, except as regards the proposed new piggeries and goat house, which seemed to be planned on too elaborate a scale for the needs of pig work at a Dairy Institute, the building scheme was generally well designed and befitting the needs of a National Institute in Dairying. A grant of £6,880 on a £ for £ basis in aid of this scheme was recommended by the Development Commissioners and approved by the Treasury.

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* Report by the Dairying and Animal Products Committee on a Review undertaken by them of Dairy Research in Progress in Great Britain, including a Review of the work of Dairy Bacteriologists in England and Wales. Agricultural Research Council Special Report Series, No. 3, 1938. H.M. Stationery Office, Price 2s.

A further important improvement which has taken place during the period covered by this Report is the increase in the number of graded workers attached to the staff of the Institute, an increase designed to give effect to the reorganisation of certain departments considered by Professor H. D. Kay, the Director, to be essential in the interests of the general efficiency of the Institute. The need for some change in organisation was emphasised by the considerable increase in the number of research workers since an establishment of graded *personnel* was made for the Institute in 1920. In that year, the total number of graduate workers engaged in research was ten. The number of graded workers was five, consisting of two in Grade I, including the Director, one in Grade II, and two in Grade III. In September, 1935, the corresponding number of research workers was 32, while the graded staff numbered seven only, consisting of the Director, three in Grade I, and three in Grade II. The proportion of graded workers to the total of research workers was thus very low and, apart from the objections which may properly be taken to the practice of paying extra salaries from maintenance, the absence of a sufficient graded establishment made effective supervision and guidance of a large number of junior workers very difficult.

The main development recommended by Professor Kay was that the Physiology Department, founded in 1930, should be put on an adequate and permanent basis. It is generally accepted that one of the most urgent needs of dairy science at the present time is a better knowledge of the physiology of lactation. Many problems of dairy physiology, e.g., those connected with the effect of hormones on milk secretion are practically untouched. Professor Kay recommended that a new Department, to be called the Physiology and Biochemistry Department, should be set up and placed in the charge of Dr. S. K. Kon who should be given permanent status in Grade II, that Dr. S. J. Folley should be appointed Biochemist in the new Department, and that a new post of Experimental Physiologist, of not less than Grade III status, should be created and filled as soon as the new laboratories were ready for occupation. Other changes proposed were that Dr. W. L. Davies should be placed in Grade II in the Chemistry Department, that Mr. A. S. Foot should be appointed to Grade III in the Dairy Husbandry Department, where the work has greatly increased in recent years owing to the introduction of new Official Schemes and Orders affecting milk production, and that Dr. J. G. Davis should be appointed to Grade II in the Bacteriology Department. The Dairying Committee recommended acceptance of these proposals, which were adopted by the Ministry of Agriculture and Fisheries and the Development Commissioners and approved by the Treasury. Subsequently, upon the retirement of Captain John Golding from the Headship of the Chemistry Department, approval was given to the appointment of Mr. G. W. Scott-Blair, a physical chemist formerly of the Rothamsted Experimental Station, as Head of the Department in Grade I.

The research programme of the Institute includes the following major problems:—

The control of the compositional (physical, chemical and bacteriological) quality of milk.—This subject falls under the three headings of (1) analysis, (2) study of the incidence of low quality in milk, and (3) physiological research. Much of the *analytical work* is being done in conjunction with the Technical Committee on Standards for use in the Dairy Industry of the British Standards Institution. Clear improvements in several directions of analytical methods for the assessment of milk quality have already taken place. A new method for the determination of fat in milk, which promises to be quick, accurate and cheap, has recently been devised, but this will need further careful work before it can be recommended as an improved standard method for this fundamental determination. Apparatus used for the freezing point test for the detection of added water in milk is under revision. The existing method has been improved to permit of greatly increased rapidity of determination, together with accuracy, and the application of this method to commercial milk laboratory practice will be studied. Other physical and colloidal properties of milk are being investigated by new and delicate methods of measurement.

A survey is being undertaken of the regional and seasonal incidence of *low quality milk* and also of the occurrence of milk notably above the average in quality in various parts of the country. Correlations have been discovered between certain herd environmental factors and the analytical findings, but these require experimental confirmation. Feeding experiments on nutritional factors which may possibly control the production of high and low quality milk are being made as animals become available in the Institute's herd.

On the *physiological* side results of considerable interest have been obtained from an investigation of the relationship between blood constituents and milk constituents, and the nature of the precursors in the blood of the milk fat and the milk phosphorus compounds has been established with some certainty. The energy metabolism of the mammary gland in relationship to milk composition is being investigated, and at the same time the possible blood precursors of the casein of milk are being examined. Attention is being given to the hormonal control of lactation with special reference to milk quality, and to the effect of thyroxine, the hormone of the thyroid gland, on milk secretion. Previous results pointing to the conclusion that thyroxine administration causes a marked increase in milk secretion and fat production in later lactation have been confirmed, and it has also been shown that the non-fatty-solids content of the milk of thyroxine treated cows is significantly increased. This last result may help to elucidate the causes underlying the secretion of milk poor in non-fatty solids, a problem of importance to dairy farmers at the present time. This work is being extended and will include a study of the effect of thyroxine administration in *early* lactation, and investigations of the influence on lactation of extracts of the anterior lobe of the pituitary, of the corpus luteum hormone and the male hormones. It will, of course, be greatly facilitated when the new laboratories are available and when it is possible to appoint an experimental physiologist to the staff.

The nutritive value of milk and milk products.—The Institute has developed a technique for assessing the changes produced in the nutritive value of milk by (1) changes in the food and environment of the lactating cow, and (2) the commercial processing of milk. Commercially pasteurised and sterilised milks and dried milk, dried by two different processes (roller and spray), have been compared with raw milk of the same original bulk. At the request of an Expert Sub-Committee of the Milk Nutrition Committee an experiment was carried out to determine if any differences could be detected between raw and pasteurised milk by the use of these milks in the feeding of calves. The experiment was begun in October, 1935, and completed in July, 1936. Thirty-two Shorthorn bull calves from tubercle-free herds were obtained when four to five days old, grouped in pairs of similar age and weight, and one of each pair given raw milk and the other pasteurised milk. The number of pairs which completed the experiment was eleven; the other five pairs were broken up by the death or removal for an adequate reason of one of each pair. Records were kept of the food consumed, the live weight gains, appearance of the calves and other relevant matters. No material differences were shown between the calves receiving the two types of milk. This similarity in results is illustrated by the average daily live weight gains—the eleven calves receiving raw milk increased during the period of six months at the rate of 1·967 lb. per head, and those receiving pasteurised milk at the rate of 1·969 lb. per head.

New methods for the estimation of vitamins in milk are being considered, and the effect of feeding artificially dried young grass on the quantity, quality and nutritive value of winter milk is being examined, both by analyses and by feeding tests with rats.

The protein requirements of dairy cows.—This work aims at determining whether a reduction can usefully be made in the food protein standards for milk production accepted and widely used in this country. During the winter of 1935-36 experiments were begun on eighteen farms with a total of over 500 cows in different parts of the south of England, and during the winter of 1936-37 co-operation was obtained from twenty-eight farms with over 900 cows. This work is not yet completed, but results of considerable practical value are assured. Other experiments in the Institute's herd have compared the use of high and low lysine concentrates for feeding dairy cows. The work has shown that the existing methods of estimating the "key" amino-acids in the protein of concentrates used for feeding dairy cattle leave much to be desired. Since a large part of the experiment turns on the quality as well as the quantity of protein consumed, attempts are being made to devise more satisfactorily methods for the analysis of the amino-acids of these proteins. In this part of the work the Institute is collaborating with Professor A. C. Chibnall, of the Imperial College of Science and Technology.

The enzymes of milk and of the mammary gland.—In 1935 Kay and Graham published details of the phosphatase test, by which it is possible, with the use of chemical reagents, to detect whether the enzyme phosphatase, a constant constituent of raw milk completely destroyed by efficient pasteurisation, is or is not present in alleged pasteurised milk.* Two simple tests were described for determining the efficiency of pasteurisation. The first may be carried out within half an hour, and will detect any gross errors of pasteurisation technique. The second is more searching and will reveal minor errors of technique such, for example, as heating 1½° F. below the minimum temperature for pasteurisation, or at the correct temperature for 20 instead of 30 minutes, or the admixture of 0·25 per cent. of raw milk with properly pasteurised milk. This test permitted a survey in 1935 of commercial pasteurised milks, and it was found that a disturbingly high proportion of pasteurising machinery, both in London and elsewhere, was functionally inefficient or unsatisfactorily operated, although plants properly designed and operated regularly provided a product which had been correctly heated. It was also shown that the milk sold to school children as "pasteurised" appeared, in a large proportion of the cases examined, to have been pasteurised in a very casual way. Both in America and in this country, the phosphatase test has proved a valuable aid in the supervision of pasteurising machinery. The Ministry of Health has drawn attention to it in a Circular issued for the guidance of Local Authorities in the granting of licences under the Milk (Special Designations) Order of 1936. A survey over the same area as that of 1935, completed in 1937, using the same test, indicated noteworthy improvement in the general efficiency of the process, not least in the pasteurisation of milk for school children. The test is being further studied and improved.

The functional and industrial significance of the phosphatase and lipase of milk is being investigated at present. A satisfactory method for the determination of milk lipase has been worked out, and a study of this enzyme in some detail is now possible. The relation of milk phosphatase to stages in lactation, normal and abnormal milks, changes in milk quality produced by hormones, etc., is throwing light on the secretory processes. A study is also being made of the significance in relation to cheese ripening of the proteolytic enzymes in raw milk.

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* "The Phosphatase Test for Pasteurised Milk." H. D. Kay and W. R. Graham. Journal of Dairy Research, Vol. VI, No. 2, pp. 191–203.

The nature and control of cheese ripening.—The lactic acid bacteria (lactobacilli and streptococci), which play an important part in cheese ripening processes, have been systematically studied in the Institute for some years. This study is being further advanced by employing serological and certain biochemical methods shown in the Institute to be of value in typing and classification, and an attempt is being made to evolve a practical scheme for the identification, without intricate procedure, of all economically important strains of these bacteria. More precise enquiry is being made into the activity of the individual enzymes, the complex of which has been shown to be mainly responsible for the more massive changes occurring in the curd of hard-pressed English cheese. Reasons are being sought for the marked difference between the quality of hard-pressed cheese made from milk pasteurised by the high-temperature short-time process and that of imported cheese, which is said to be made from pasteurised milk. The mineral content of cheese of various types made from raw and from pasteurised milk is also being investigated, particular attention being paid to determining the stages at which the salts present in the original milk are lost during manufacture. Other cheese studies include the effect upon quality of cheese made from the milk of cows suffering from chronic mastitis.

Grants have been received from the Milk Marketing Board in aid of the work on the compositional quality of milk, the protein requirements of dairy cows, and cheese ripening, and this assistance has enabled six extra temporary assistants to be appointed.

Outside this main research programme the Institute maintains a continuous study of the inheritance of milk production, and the methods by which the value of bulls can be proved by the records of their progeny. The results here have enabled the Live Stock Branch of the Ministry of Agriculture to devise a Progeny Recording Scheme for use by members of Milk Recording Societies. Experiments on the winter feeding of dairy heifers is undertaken each winter and much useful information on the standard food requirements of young dairy stock and on the suitability of commercial winter rations has been, and is being, collected. Work with pigs includes experiments on the influence of anaemia and vitamin A deficiency on disease resistance, carried out in conjunction with the Veterinary Laboratory of the Ministry of Agriculture and Fisheries, and researches on low and high levels of feeding of bacon pigs and on the storage of vitamin A following dosage with vitamin A concentrate. The effects on the bacteriological status and the commercial qualities of milk of high-temperature short-time pasteurisation are being studied, and the performance in commercial practice of bottle washing machines and methods for the control of their efficiency have been investigated. The bactericidal properties of detergents under commercial conditions are being measured and the types of surviving organisms determined.

The Institute is entrusted with the testing of dairy machinery under the Agricultural Machinery Testing Scheme of the Ministry of Agriculture and Fisheries, and, as stated above, the buildings are being improved to meet the needs of this work.

A problem of the Institute to which the Dairying Committee gave some considerable attention is the volume of work of an advisory character undertaken. Increased activity in the dairy industry in recent years has been reflected at the Institute by a growing demand for advisory services, and has led to a greater proportion of the time of the more experienced members of the staff being taken up in meeting it. These activities, though they provide evidence of the confidence felt in the Institute by the agricultural community and supply valuable information about practical problems, have steadily encroached on the time available to the senior staff of the Institute for original research, and for the careful training and supervision of a large number of junior workers which is required if their work is to be of real value. The interests of fundamental dairying research must be the paramount consideration in framing the policy of a National Institute, and, in the Council's view, the proper way for the Institute to exert its influence in the direction of advisory work, except perhaps as regards dairy husbandry to a limited extent, is through the County staffs and the Advisory Officers, who are specially appointed for the purpose, and not directly on the farmer. In cases where the County Organiser or Advisory Officer is unable to deal with an enquiry immediately, he is free, of course, to refer to the Institute for advice. This problem of securing a substantial easement from the burden of advisory work cannot, the Council agree, be achieved at once. The Institute must naturally be anxious to retain friendly relations with the farming community; but the aim should be a gradual diminution of the calls upon the time of the staff of the Institute to the point at which it is possible for the Institute's main programme to be pursued with reasonable freedom from outside enquiries not strictly relevant to that programme. The Dairying Committee recommended that the Ministry of Agriculture should explore, in consultation with Professor Kay, the best manner in which this result might be brought about.

The general impression formed is that the direction of the Institute is inspired by a clear insight into the whole subject of dairy research, and that full use is being made of the resources of the Institute in tackling problems of primary importance. The programme outlined above, in the framing of which Professor Kay has displayed scientific vision and a wide knowledge of the most urgent needs of the dairy industry, is being carried forward by the staff as a whole with enthusiasm and ability and in a spirit designed to encourage the promotion of good team work. There does not appear to be any unnecessary duplication of work between Reading and the Hannah Dairy Research Institute in Scotland.

The Hannah Dairy Research Institute, Ayr.

The graded staff of research workers at the Institute now consists, in addition to the Director, Dr. Norman C. Wright, of four Grade II workers (in animal husbandry, veterinary pathology, nutrition, and biochemistry), and one Grade III worker (in bacteriology). In addition, a temporary assistant is engaged on milk products work.

During the period covered by this Report the Council, at the request of the Treasury, have advised upon the Institute's programme and order of expenditure during the five years' period 1936 to 1940. A programme for this period prepared by the Institute was carefully considered by the Council's Dairying Committee in consultation with a representative of the Department of Agriculture for Scotland and with the Director of the Institute. The research programme provided for no material expansion, but rather for the consolidation and intensification of existing lines of work. The estimates of expenditure for the period were considered to be not unreasonable, but the Council will, in accordance with the established practice, make the usual detailed annual scrutiny of the estimates before submitting their recommendations upon applications for State grant aid; and they do not necessarily feel themselves committed to the estimates contained in the five years' programme.

The research programme of the Institute falls under the three headings of biological research, technical research and special investigations. *Biological Research* in progress is concerned with the following problems:—

The protein requirements of dairy cows, and the utilisation of home-produced feeding stuffs.—Previous investigations on the nutritive value of the proteins of various foodstuffs showed that there were marked differences in the *quality* as well as the *quantity* of the proteins of different foodstuffs, and that, in general, the best sources of protein were certain home-produced feeds, notably dried blood meal, grass, and bean meal. In a special study of the nutritive value of the proteins of young grass, little or no difference was found between the proteins of fresh grass, ensiled grass (using A.I.V., molasses, and ordinary silage) and artificially dried grass. Spring grass was markedly superior to autumn grass as a source of protein for milk production, but the proteins of autumn grass were found to be equivalent to bean meal, a source of good quality protein. A point of importance noted was that two poor quality proteins may possess a supplementary value for one another, a deficiency in one being counterbalanced by adequacy in another. It has been shown that the protein requirement for milk production can be reduced by at least one quarter (i.e., from 0·6 to 0·45 lb. protein equivalent per 10 lb. milk) provided the rations are judiciously selected. Since the nutritive value of a given protein for milk production is associated with its amino-acid composition, and particularly with its content of lysine, the methods of amino-acid analysis commonly employed are being re-investigated in order to determine their reliability. As indicated above (p. 289) work on the protein requirements of dairy cows, including an attempt to devise more satisfactory methods of amino-acid analysis, is also being carried out at the National Institute for Research in Dairying.

The relative value of raw and pasteurised milk for calves.—A comprehensive review published by the Institute in 1933* showed that the evidence regarding the relative value of raw and pasteurised milk for calves was conflicting. The results of previous experiments have been largely vitiated by lack of adequate numbers of experimental animals with " controls ", and by the absence of accurate " balance " experiments. The

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* " The Nutritive Properties of Milk in Relation to Pasteurisation ". J. D. Stirling and J. H. Blackwood. Hannah Dairy Research Institute, Bulletin No. 5.

Institute has, therefore, attempted to supply the requisite information on which a valid conclusion can be based. In the first place, experiments, planned on a " change over " principle, showed no significant differences in the assimilation or retention of nitrogen, calcium and phosphorus by calves fed on the two types of milk. In the second place, 92 calves were used in a direct feeding experiment, roughly half the calves being fed on raw milk and half on pasteurised milk. Nineteen calves (five in the pasteurised and fourteen in the raw milk-fed group) died from intercurrent infections before completion of the period of 12 weeks' experimental feeding. The results from the 73 calves which completed the feeding period showed no significant differences in the effect of the two types of milk on growth rate, nor on the condition of the calves at the end of the experiment as indicated by independent reports of four experienced judges of dairy cattle. Post mortem examinations made on all the calves revealed the value of pasteurisation in protecting the animals from tuberculous infection. None of the calves fed on pasteurised milk showed any tuberculous lesions, and although one animal reacted to the tuberculin test, exhaustive search failed to reveal any trace of infection. Of 36 calves fed on raw milk, however, 24 reacted to the tuberculin test, and 23 (or 65 per cent.) showed gross tuberculous lesions on post mortem examination. An opportunity was taken of checking the tuberculous infection of the milk by guinea pig inoculation. Of 47 samples of mixed raw milk, 33 (or 70 per cent.) showed the presence of viable tubercle bacilli. After pasteurisation, the same milks failed to reveal a single positive sample. The results of this investigation have been published.* The nutritional results here correspond to those obtained at Shinfield (see p. 289).

The biochemistry of milk secretion.—Work has been in progress at the Institute for some years with the object of elucidating the factors controlling milk secretion. A careful study has been made of the variations which occur in the composition of blood as a result of changes in the level of feeding and also as a result of salivary secretion. Particular attention has been devoted during the past two years to a study of the quantity and quality of fat secreted by the lactating cow, since the milk fat is of special importance to dairy farmers. Iodised fat has been included in the food of the cow with the object of differentiating the fat derived from the food from that stored in the animal body. The employment of this " labelled " fat shows that the concentration of dietary fat in the blood reaches a maximum about two days after administration, and that the amount of the " labelled " fat in the milk is closely related to the amount present in the blood. Progress in work of this nature is inevitably slow, and immediate practical results cannot be looked for. The subject also forms part of the Reading Institute's programme, and it is amply wide enough to justify work at both Institutes, provided that contact and co-operation are maintained.

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* "The Relative Value of Raw and Pasteurised Milk in the Feeding of Calves". J. Wilkie, S. J. Edwards, A. B. Fowler and N. C. Wright. Journal of Dairy Research, Vol. VIII, No. 3, pp. 311–323, October, 1937.

Crop and stock husbandry.—Apart from the more strictly scientific problems outlined above, investigations are continually in progress on the Institute's farm with the object of testing new methods of crop and stock husbandry. The construction and equipment of cattle byres have, in particular, been under examination. During the past five years a number of different types of byre flooring have been tested. Special attention has recently been given to the use of rubber and rubber plastics. Rubber blocks and mats have been found unsatisfactory, but two types of rubber plastic flooring have proved themselves ideal for the purpose. The flooring is resilient and warm, and is sufficiently soft to prevent the severe concussion which leads to knee and hock bruising. It is non-slippery if kept clean, and has withstood constant use for over two and a half years without showing any sign of wear. As regards byre equipment, tubular fittings, although showing great advantages over the older types of equipment, have not been found entirely satisfactory, especially from the point of view of bruising. Experiments are in progress to determine how these disadvantages can be overcome.

Bovine Tuberculosis.—In 1929, an experiment was promoted with the aid of the Medical Research Council to determine the extent to which tuberculosis could be eradicated from a group of dairy herds by providing the relatively small incentives of free tuberculin testing and free expert advice on the isolation of reactors and the rearing of young stock. At the conclusion of the scheme fears were expressed that, with the cessation of free testing, a large proportion of herd owners would take no further steps to combat infection, and that the promising results achieved would be found to be of a transient nature. In 1936, therefore, it was decided to re-test the whole of the herds in the experimental area. The results of this investigation, which have been published,* showed that although no free testing had been available for three years, further substantial progress had been made. Of the 30 herds in the experimental area, 24 were free from reactors, 14 being licensed under the Milk (Special Designations) Order and eight being attested under the Attested Herds Scheme. Only five herds showed no consistent improvement, either through lack of enthusiasm on the part of the owners or because the nature of the premises made eradication abnormally difficult. Among neighbouring herds the results showed that the experimental area had acted as a leaven from which eradication has spread on a remarkable scale. Of 192 herds included within a five-miles radius of the centre of the area, 17 were licensed and attested, 31 were licensed, and 16, although unlicensed, were free from reactors; that is to say, 64 herds, or one-third of all those within the five-miles radius, were free from infection.

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* " The Eradication of Bovine Tuberculosis. Further Results ". S. J. Edwards. " The Veterinary Record ", 1936, *16*, 561.

Other work in progress at the Institute on the control of disease in dairy cattle is referred to in the section of this Report dealing with Animal Diseases (pp. 217-284).

Technical Research is in progress on the following subjects: —

The pasteurisation of milk.—One disturbing feature of an enquiry carried out in 1933 into the tuberculous infection of the milk supplies of Scottish cities was the appearance of positive tuberculous samples among milks which were stated to have been pasteurised by the " holding " method. A detailed survey since carried out into the design, operation and efficiency of pasteurising plants has now been published.* In one respect the results of the enquiry were particularly striking as showing that the occasional presence of infected milk was associated with gross defects in both the design and operation of the processing plants concerned. Similar findings resulted from the survey carried out by the National Institute for Research in Dairying (see p. 290). Taken as a whole the efficiency of the plants inspected during the course of the Hannah Institute enquiry was reasonably satisfactory. Apart from technical recommendations, the report contained three suggestions for ensuring greater efficiency in the technique of pasteurisation, namely, (1) a relatively larger margin of profit to distributors whose plants are efficiently supervised, (2) the institution of a course of instruction for plant operators, and (3) an extension of routine laboratory control throughout processing.

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* " An Enquiry into the Design, Operation and Efficiency of Pasteurising Plants ". A. W. Scott and N. C. Wright. Hannah Dairy Research Institute, Bulletin No. 6.

Methods of manufacture of evaporated milk and canned (sterilized) cream, and of dried milk.—Special attention has been given by the Institute since its establishment to problems connected with the condensing and drying of milk and the manufacture of canned milk products. A valuable range of processing machinery has been acquired which has enabled the Institute to undertake the production of evaporated milk and canned cream on a small commercial scale, so that the results arrived at in the laboratory can now be tried out under practical conditions. In studying the conditions of production and the properties of dried milks, the Institute has been able to secure the co-operation of the Department of Mechanical Engineering of the Royal Technical College, Glasgow. A small scale spray drying plant has been erected, and investigations have been made into the factors affecting heat transfer and evaporation.

Defects in canned (sterilized) cream.—An investigation is being undertaken of various defects, such as acid coagulation, gas formation ("blowing"), and the development of various undesirable flavours, which occur in canned milk products as a result of contamination with micro-organisms. A special study has been made of bitterness in canned (sterilized) cream, which occasionally is a source of a serious loss to manufacturers. Pure cultures of the contaminating organisms have been isolated and identified as strains of the aerobic spore-former *B. subtilis*, and it has been found possible to reproduce the fault by re-inoculation into sound cans. The spores of the contaminating organisms are capable of withstanding remarkably high temperatures and, consequently, it may be difficult to overcome the defect by any alteration in the method of processing the cream. The only sure means of preventing its occurrence appears to be the improvement in the quality of the original milk supply. The fact that the defect may fail to develop in affected cans for several weeks points to the need for retaining canned cream in storage for reasonably long periods, if defective cans are to be prevented from finding their way on to the market. Another defect, black discoloration, is caused by the liberation of sulphur compounds from the milk proteins and the subsequent reaction between these compounds and the metal container. This defect can be controlled by adjustments in the time and temperature of heating and by alterations in the addition of neutralising or stabilising agents.

Factors affecting the solubility of milk powders.—Dried milk powders vary widely as regards their solubility in water, but until recently the factors affecting solubility have not been understood. An investigation has established that the factors concerned are three-fold: the temperature of heating, the time of heating, and the concentration of milk solids. The relative influence of these three factors has been studied, and the practical limits of heat treatment indicated. Attempts are now being made to apply the conclusions of the work to commercial drying conditions. As a result of this work, a re-investigation has been made into the methods of determining the solubility of milk powders. The importance of temperature of reconstitution has been demonstrated, and it has been shown that solubility measurements may be used as a rough index of the thermal conditions existing in a commercial plant. During the course of these investigations it became apparent that the factors affecting the solubility of milk powders were closely allied to, if not identical with, those responsible for the heat coagulation which frequently occurs in evaporated (condensed) milks. The investigations are, therefore, being extended to include a study of the denaturation of milk proteins, with special reference to the heat coagulation of evaporated milk.

Special Investigations relate to the following:—

The consumption of milk by children of school age.—Although the milk-in-schools scheme was commenced in the late autumn of 1934, no arrangement was apparently made to ascertain the extent to which milk was then being consumed by children. Thus, no basic figure was secured on which the ultimate success or failure of the scheme could be judged. With a view to making good this omission, an extensive survey* was undertaken by the Institute, information being secured regarding the milk drinking habits of a large number of school children in Glasgow and Ayrshire. It is intended that a similar survey should be carried out after an interval of four or five years (provided that the milk-in-schools scheme is continued throughout this period), so that figures may be available to determine whether the milk drinking habit has been changed as a result of the operation of the scheme. In the meantime, an analysis of the figures obtained from the survey has revealed many interesting facts about the influences of income level, age, sex, and other factors on milk drinking, and concerning the relative demand for milk in comparison with other beverages. Of the 13,317 children included in the inquiry, 7,017, or over one-half, did not drink milk at all, while 4,323, or roughly two-thirds of the remainder, only took it once daily. An examination of the effect of age on milk drinking showed (contrary to expectation) that the results for the younger children were on the whole no better than those for the older children. The effect of other factors which might influence milk drinking, such as the consumption of other beverages and of condensed milk, was examined. The results of the survey suggest that the two chief factors responsible for low milk consumption are poverty and dietary habit.

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* "An Enquiry into the Drinking Habits of Children of School Age, with special reference to Milk Drinking". Norman C. Wright. Hannah Dairy Research Institute, Bulletin No. 7.

An experiment with flavoured milk.—During recent months there has been a serious falling off in the number of children who take milk under the milk-in-schools scheme. It appeared that this might be due to a distaste for plain milk, and an experiment was, therefore, conducted in co-operation with the Scottish Milk Marketing Board in which flavoured milks were provided as an alternative to plain milk at certain selected schools in Ayrshire. It was found that, if the children were given a free choice, the demand for flavoured milk was greater than for plain milk, but the provision of the former failed to effect any permanent increase in the number of children taking milk.

The Council's general conclusion is that, while the work of the Institute is varied, it forms in the main a co-ordinated whole, excellently conducted and arranged so as not to overlap the work of the Reading Institute. The staff, under Dr. Wright's able direction, give the impression of being capable, keen and interested and appear to be attacking problems of importance with confidence and by well-judged methods.

The West of Scotland Agricultural College, Auchincruive, Ayr.

Advisory and investigational work in the field of dairying at Auchincruive is carried out by Professor R. H. Leitch, Advisory Officer in Milk Utilisation,* and by Dr. A. C. McCandlish, Advisory Officer in Milk Production. In addition, Dr. J. F. Malcolm, Lecturer in Bacteriology at the College, combines his teaching duties with a certain amount of bacteriological research under the general direction of Professor Browning of Glasgow University. The Development Fund bears the cost of the advisory services provided by the Departments of Milk Utilisation and Milk Production.

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* Since this Report was prepared, the Council have learned, with deep regret, of the death of Professor Leitch.

The primary aim of the research and advisory work of the *Milk Utilisation Department* is the improvement of the quality of milk and its manufactured products. Close contact with primary producers is maintained through the co-operation of the County Instructors on the College Extension Staff, and problems which require systematic investigation are constantly referred to the Advisory Officer. Work of this nature takes precedence over other experimental investigations, as such service is considered to be of most immediate benefit to the industry.

Market milk investigations concern the study of the different sources of contamination of milk during its production on the farm, the types of bacteria associated with contamination, and the specific effects produced by the contaminants on the flavour and market value of milk. In recent years flavour defects from various causes have become prominent, and increasing numbers of samples of faulty flavoured milk have been submitted for examination and advice by milk producers and milk dealers. The bacteriological aspects of pasteurisation have been studied with a view to suggesting improvements in the handling and processing of milk in depots and the treatment of milk equipment. Advice has been given on a number of technical problems, such as the formation of foam in processing, variations in the cream line, re-contamination of the pasteurised milk from the equipment and the final package, cleansing and sterilisation of milk plants and milk bottles.

An investigation has been made of the factors affecting the body, flavour and keeping properties of cream pasteurised to different temperatures. Work carried out during recent years on butter has been concerned with the effects of specific foods on flavour, body, texture, and stability, with the effects of selected lactic bacteria on aroma, flavour and keeping properties, with different systems of pasteurising cream for butter-making, and with defects in farm and factory butter, and their causes.

Cheese-making investigations have been in progress for the past 25 years. As the quality of cheese (independent of variety) is largely controlled by the quality of the primary milk, special attention has been directed to methods for assessing the cheese-making properties of milk. The studies have also embraced (*a*) improvements in the process of manufacture, with particular reference to Cheddar and Dunlop Cheese; (*b*) the employment as starters of selected lactic acid bacteria in cheese-making, and the effects of such organisms on the flavour and texture of ripe cheese; (*c*) comparison of rennin and pepsin as coagulating agents for cheese-milk, and the relative effects of these enzymes on the texture and on the rate of ripening of hard-pressed cheeses; (*d*) the manufacture (from raw materials of local origin) of rennet with satisfactory keeping properties and high potency, and free from putrefactive bacteria; and (*e*) the study of impurities in raw materials (rennet, salt, annatto) of commercial origin, which cause specific defects in cheese. Particular faults in cheese, such as discoloration, flavour and texture defects, and defects in the finish or rind of cheese, which seriously impair its market value, have been investigated and reproduced experimentally. The various causes of slow-working in cheese making, the restraining influence of certain types of milk, the antagonistic effect on the lactic acid fermentation of contaminating bacteria, and the noxious influence of mastitis milk have been made the subject of investigation and experiment. Lately, the employment of specially designed small scale cheese-making equipment has enabled an accurate study to be made of the cheese-making properties of the milk of individual cows.

Experiments on the pasteurisation of cheese-milk, begun before the war, have been continued regularly since, and the significant effects of the process on the flavour, body, texture and rate of ripening of cheddar cheese have been recorded. The work has shown that the " holding " method will give the best results, provided that a critical maximum temperature of heating is not exceeded. Such minor modifications of the technique of manufacture as are required to ensure a ripe cheese with normal characteristics, when pasteurised milk has been used in its making, have been determined by large scale experiments. Local cheese factories, following the technique recommended, have reported good results. Cheshire cheese with the characteristic flavour and texture has been made from pasteurised milk. Flash pasteurisation has been found to result in a definite change in the cheese-making properties of milk; the texture of the curd is affected adversely, and the mature cheese lacks the distinctive quality of a ripe raw milk cheese. Attempts are being made to ameliorate the texture by the addition of various salts to the heat-treated milk at the outset, and to secure the development of the desirable flavour and ripening by the employment of special starters.

The *Milk Production Department* was started in 1922. Experimental work is carried out on the College farm and on other farms as occasion arises. A study of the records of the

Scottish Milk Records Association showed that the improvement in milk production in Scotland in the last 20 years had been brought about mainly by better feeding and management, while little improvement could be attributed to breeding. In the hope of getting information on this problem which might be of value to farmers and breeders, a study was made of the records for two dairy breeds, Ayrshire and Friesian. A list has now been prepared of over 700 Ayrshire and over 80 Friesian proven sires, each of which has 10 or more daughters yielding at least 280 lb. of butterfat, or 224 lb. as a heifer, in a lactation not exceeding 52 weeks, and calving again within 15 months of the start of the lactation. A study has also been made of the sires and grandsires of the Ayrshire proven sires. The conclusion reached by Dr. McCandlish is that, in choosing a bull which it is hoped will sire high yielding daughters, attention should be given first to seeing that he has a proven sire, and then a proven paternal grandsire. The collection of data regarding the influence of the dam, to which other workers have attached much greater importance, is only at a very early stage.

A series of trials is being carried out on the value of succulent foods in the dairy ration. Swedes, mangolds, carrots, marrowstem kale, potatoes, beet pulp, silage and A.I.V. fodder have all proved to be of the same value, when compared on the dry matter basis. Choice between the succulent food depends on local conditions—the one to use is that which provides dry matter at the lowest cost per pound.

Work has been carried out on the use of colostrum in reducing the incidence of calf diseases. Dr. McCandlish finds that the feeding of colostrum to the new-born calf for the usual period of four days is not sufficient and that feeding for a week is not too long. In the experimental work a greater incidence of disease was present in the five days' group than in the ten days' group.

In certain districts hoven, or bloat, a condition in which gas collects in the stomach of the animal and renders the near (left) side tympanitic or " swollen with wind ", is very prevalent among dairy herds. The trouble is thought by Dr. McCandlish to be mainly due to a saponin in wild white clover. Several methods of attack have been tried; the most promising is work on liming and manuring, which is being carried out in co-operation with the Soils Department of the College. The lack of lime seems to be one of the factors, and also, possibly, a disturbance of the potash-nitrogen ratio in the soil. Other work includes a study of the protein supply of dairy cattle in which an attempt is being made to devise rations which will give as good results as bean meal, a source of protein of good quality, but at a lower cost.

Dr. Malcolm of the *Bacteriology Department* has carried out an investigation of the plating method for estimating the number of bacteria in milk by means of series of 20 parallel plates. He found that there was close agreement between the parallel plate counts on samples containing less than 5,000 organisms per ml., but a great variation on samples whose bacterial content was more. Taking the mean of 20 parallel plate counts as standard, the results of duplicate plate counts were misleading in 21 per cent. of the samples, whereas those of five parallel plate counts were misleading in only 4 per cent.

The incidence of coliform bacteria in milk was found to be lower in winter than in summer, there being a marked correlation between the proportion of coliform positive samples and the mean atmospheric temperature. The ratio of *B. coli* strains to other coliform strains isolated from the milk of cows confined to the byre was roughly 7:3 and from the milk of cows at pasture 2:3. Because of the comparatively high incidence of aerogenes types of coliform bacteria in unpasteurised milk, a study was made of the source of these types, with special reference to their presence in bovine faeces. Such organisms are widely accepted to be of non-faecal origin. It was found that, when ordinary methods of isolation were used, the organisms, with few exceptions, belonged to the typical *B. coli* types, especially *B. coli communior* and *B. coli communis,* but that, when selective enrichment methods were employed, other types of coliform bacteria, i.e. aerogenes-cloacae types, were almost always present, although in small numbers. Thus, the coliform flora of bovine faeces was found to correspond closely with what various other workers had found in the case of human faeces. Further, there was no significant variation in the types of coliform bacteria in the bovine faeces under winter and summer conditions. In view of the fact that aerogenes-cloacae types, although almost always present in bovine faeces, occur in relatively small numbers in each specimen, a further investigation was carried out to determine whether these organisms may not become enriched in milk held in low temperatures such as are used in dairy practice. It was found that aerogenes-cloacae cultures as a rule multiplied much more rapidly than *B. coli* cultures at 16° and 20° C., but that at 30° and 37° C. the reverse was the case. From these facts it may be inferred that if milk, which is contaminated with faecal matter, is kept at 16° to 22° C., it may contain ultimately large numbers of aerogenes-cloacae types, even when these organisms occurred scantily in the faeces.

A large number of samples of market milk is examined monthly for mastitis. During this routine work opportunity is taken to determine the incidence of mastitis infection in various districts in the College area, and the most satisfactory method to employ for the detection of such milk. It has been found that there is a considerable increase in the proportion of mastitis infected samples at the period of the year (May and June) at which cows are put out to grass. At present it is an open question as to what factor is responsible for this increase, but the tests are being continued.

An investigation to determine the value of a medium containing certain concentrations of telluric acid for the detection and isolation of streptococci from faeces, etc., showed that while streptococci can grow in high concentrations (1: 100 and 1: 200) of telluric acid, coliform organisms are inhibited by concentrations of 1: 5,000 to 1: 15,000 and *B. proteus* by concentrations of 1: 400 or 1: 500. This work, so far as it has gone, has given indications that enrichment media containing telluric acid might well be used for the detection and isolation of streptococci from faeces, water and milk.

The Edinburgh and East of Scotland College of Agriculture.

The duties of Dr. Cunningham, Advisory Officer in Agricultural Bacteriology at the College, are not confined to dairying problems, but cover other subjects such as microflora of the soil and the causal organisms of plant diseases. Much of the research in dairying arises out of advisory work. Like Dr. Malcolm at the Glasgow College, Dr. Cunningham has paid special attention to the types of coliform organisms in milk with a view to determining their source. He has found that, while typical *B. coli* is responsible for a large proportion of such contaminations, milk samples may also contain considerable numbers of atypical *B. coli* forms known to occur on grains and in soil. He is of opinion, however, that it is improbable that contamination with dust derived from these sources can account for the numbers of atypical *B. coli* often found in milk. Mere faecal contamination offers an inadequate explanation because, while atypical *B. coli* do occur in faeces, the ratio of atypical to typical in this medium is much lower than that found in milk. The possibility that atypical forms grow more rapidly in milk than typical *B. coli* was investigated, but it was found that the rate of multiplication of typical *B. coli* generally outstripped that of atypical coli. While the atypical forms are not as a rule harmful to health, they are of considerable importance from the dairying point of view, since they frequently cause defects in manufactured products.

Studies of media for the determination of the bacterial content of milk samples have occupied much of the attention of dairy bacteriologists in recent years. A comparison was made by Dr. Cunningham of standard agar with the medium recommended by Wilson in his report on the Bacteriological Grading of Milk. This showed that, for a small number of samples, Wilson's medium was markedly superior to standard agar. Dr. Cunningham is undertaking an examination of the organisms responsible for these high counts with a view to determining whether they are mastitis streptococci. Mastitis organisms are found in a large proportion of the samples received in connection with the advisory service, e.g., in samples which exhibit taints. An investigation has been made of methods for the detection of the causal organisms in milk samples and testing on the lines recommended by Professor F. C. Minett and his co-workers at the Royal Veterinary College, London, had been begun in two herds with a view to ultimate eradication of the disease.

The work in relation to dairy research of the Division of Bacteriology and Immunology of the London School of Hygiene and Tropical Medicine.

The Bacteriological Grading of Milk.—The principal investigation of recent years undertaken in this field by Professor G. S. Wilson and his assistants at the London School of Hygiene and Tropical Medicine has been a comprehensive and critical enquiry into the validity of the methods available for the bacteriological grading of milk.*

Professor Wilson's investigations, which occupied three years, covered an examination of the different tests—the plate count, the coliform test, the methylene blue reduction test, the Breed smear method, the brom-thymol blue test and various other miscellaneous tests, and an estimation of the experimental error of the more important of these tests. In the interpretation of the results of the experimental data care was taken to avoid subscribing to the common *a priori* assumption that the plate count must be the final standard of reference. Instead, the assessment of the relative value and precision of current procedures, and the defining of a simple test by which the grading of milk in terms of its contents in living bacteria might be reliably performed, were obtained by submitting different types of milk to examination by most of the important tests, and by working out the degree of correlation, not only between different pairs of tests, but between each test separately and the hygienic conditions under which the milk was produced on the farm.

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* "The Bacteriological Grading of Milk". Medical Research Council Special Report Series, No. 206.

Wilson draws attention to the necessity for bearing in mind the fact that each test affords an answer to a separate question. There is no one test capable of measuring satisfactorily the real cleanliness of milk, and most of the tests used afford only a partial and indirect answer. Perfect agreement is, therefore, not to be expected in the answers given by the different tests. Wilson laid down a few broad principles, which he suggested should be kept in mind in deciding what answer or answers should influence the selection of a test. These principles were as follows:—

(1) that the cleanliness of the milk of any given producer should be judged, not on the basis of one or two samples taken at some particular season, but on samples taken frequently and regularly throughout the year;

(2) that, however many samples are tested, no producer or distributor should be penalised on the basis of any one sample;

(3) that separate standards for summer and winter should be laid down, since atmospheric temperature plays such an important part in determining the bacterial content of milk. It was suggested that the summer standard should operate during May to October and the winter standard during November to April;

(4) that, because many factors affect the results of examination of any one sample, the too fine sub-division of milk into classes of cleanliness should not be attempted, as such sub-division would suggest accuracy in classification which may be definitely misleading;

(5) that the system obtaining at the time of the enquiry of concentrating on the cleanliness of Certified, Grade A tuberculin tested and Grade A raw milk, which formed but a fraction of the total liquid milk consumed, and left the bulk of the milk to take care of itself, should be revised. The principle to be adopted should be to insist on the grading of all milk destined for human consumption.

Wilson concluded that the sediment test, the leucocyte count, the titratable acidity, the H-ion concentration, the increase in acidity, the brom-thymol blue test, the keeping quality test, and the laboratory pasteurisation test, though undoubtedly of use for certain special purposes, could not be regarded as suitable for the routine grading of milk. With regard to the coliform test, none of the premises on which the use of this test for the control of water supplies is based holds good for milk. Its use in the grading of raw milk was not considered to be justified, though for pasteurised milk it was thought to be of some value, since it might serve as an index of the efficiency of the processing, if performed on freshly pasteurised milk, or as an index of the subsequent contamination or exposure to unsuitable temperatures, if performed on bottled milk at the time of delivery to the consumer. The experimental error of the test is, however, very large, and on this account the results should preferably be reported, not in absolute numbers, but as above or below an arbitrary standard. The Breed smear method is of greatest value in the rapid grading of milk, and is of much service at collecting stations where milk from individual farms is bulked before despatch to large towns in rail or road tanks. As a general test, however, for the routine examination of large numbers of samples, the method was believed to be less suitable than the modified methylene blue reduction test described in the report. The plate count test was severely criticised. Ostensibly it measures the numbers of bacteria in milk, but in fact it does not. On account of the difference between various species of bacteria in their nutritional, respiratory and temperature requirements, on account of the fact that many organisms may be dead, and, most important of all, on account of the gross irregularity in the distribution and clumping of the organisms in the milk, the plate count merely registers the number of bacterial units capable of multiplying under the particular conditions selected. Since the average number of bacteria per clump is variable from one milk to another, and from time to time in the same milk, and since these clumps may disintegrate to a quite uncontrollable extent during the process of dilution, it follows that the figures yielded by the plate count are arbitrary, not strictly comparable from milk to milk, merely approximate, and have no absolute significance. The technique is complex, is difficult to standardise, and requires highly skilled workers. Even in favourable conditions, with the method standardised as far as possible, the experimental error is very large, and on any one count an allowance of ± 90 per cent. may have to be made. Besides demanding costly apparatus and a delay of at least two days in the result, the plate count seems to afford no better index of the sanitary conditions of production or of the keeping quality of the milk than the Breed test or the modified methylene blue test. The quantitative expression of the results in figures extending over a wide range affords a fictitious appearance of accuracy, which leads to a wholly unjustifiable feeling of confidence in their value. It was, therefore, recommended that the plate count test should be discontinued as a method of grading ordinary raw milk.

The modified methylene blue reduction test appeared to fulfil most of the requirements demanded of a test for the routine grading of raw milk. It is a simple inexpensive test, with a very small experimental error, which can be carried out by relatively unskilled workers on large numbers of samples. It demands a minimum of equipment, it is capable of classifying milk on the basis of cleanliness into the maximum number of grades desirable, and it affords on the whole a very good index of the keeping quality of the milk. Besides these advantages, it gives more information about the milk than does the plate count. The result does not appear to be seriously affected by the degree of aggregation of the organisms in the milk, and the test is a very much more sensitive index than the plate count of bacterial growth. The essential modification consists in the half-hourly inversion of the test tubes, which to a great extent prevents the accumulation of the cream, together with large numbers of bacteria, at the surface, and the consequent establishment of irregular zones of reduction throughout the milk. Seventy-five per cent. of samples of morning milk, left at atmospheric temperature for 12 hours after milking and subsequently refrigerated overnight, should have a reduction time of over 5½ hours in the summer and of over 6½ hours in the winter. The same standard should apply to evening milk left at atmospheric temperature for 18 hours and examined directly. These suggested standards applied to milk of the old Grade A quality.

The Milk (Special Designations) Order, 1936, made by the Minister of Health in April, 1936, revoked the Milk (Special Designations) Orders of 1923 and 1934. It provides for the use of three designations in relation to milk, viz., "Tuberculin Tested", "Accredited", and "Pasteurised". For the examination of raw Tuberculin Tested milk and Accredited milk, the bacterial count (as determined by the plate count method) is replaced by the modified methylene blue reduction test as recommended by Wilson, with the exception that the reduction times for summer and winter samples are reduced from 5½ hours and 6½ hours to 4½ hours and 5½ hours respectively. A full description of the test, as now officially used, is given in the Ministry of Health's publication Memo. 139/Foods (January, 1937). The Department of Health for Scotland also issued, in July, 1936, a new Milk Designations Order prescribing four special designations as follows:—" Certified ", " Tuberculin Tested ", " Standard ", and " Pasteurised ". The methylene blue reduction test has not, however, been adopted for use in connection with the grading of milk in Scotland.

Mention may be made here of a number of other investigations, which were carried out following the publication of Professor Wilson's report, into the comparative merits of the methylene blue reduction test and of bacteriological methods in assessing the quality of milk. Professor Leitch and Dr. Malcolm of the West of Scotland Agricultural College examined 8,085 samples of milk over two successive periods in 1935 and they took as the basis of reference first the standard of Grade A milk as determined by the bacterial count and the incidence of *B. coli,* and secondly the reduction test. They obtained results which showed no substantial agreement between the bacteriological tests and the reduction test. They went on to point out that different kinds of bacteria vary with regard to their reducing capacity. *Streptococcus lactis,* the common milk souring and starter organism, is a powerful reducer, and milk in which this organism is prevalent may decolorise methylene blue quickly and on this account be placed in a low grade; on the other hand, mastitis streptococci have low reducing capacity and mastitis infected milk may give a good reduction test.

Later in 1935-36 a similar investigation was carried out by Mr. Edwards and Miss Nichols of the Hannah Dairy Research Institute. In contradistinction to the findings of Leitch and Malcolm, these workers found that the correlation between the plate count and reduction test was remarkably high, the correlation coefficients agreeing closely with those obtained by Wilson. The reduction test and the plate count were also compared with other measures of cleanliness by correlating them with three other laboratory tests, viz., keeping quality, presumptive coliform test and laboratory post-pasteurisation count, and with the conditions of milk production as judged by farm inspection. Both the plate count and the reduction test showed a fairly high correlation with the keeping quality and presumptive coliform tests. but the correlations with the laboratory post-pasteurisation counts were only moderate. Taken as a whole, however, the results showed that the reduction test gives as good correlations with other tests of cleanliness as does the plate count. All the correlations between farm inspection scores and plate count or reduction test were of a low order. The highest correlations were shown with the total score for methods of production; the remaining correlations were so low as to be of little significance. As regards the suggestion that the results of the reduction test might be seriously invalidated by the presence of abnormal milk and particularly by milk from cows affected with mastitis, Edwards and Nichols found that so far as *mixed* milks were concerned, the presence of milk from herds containing animals infected with streptococcal mastitis does not invalidate the methylene blue reduction test.

In February, 1936, the Advisory Dairy Bacteriologists arranged for a series of experiments on milk tests to be carried out on a co-operative basis in a number of areas in England and Wales. The experiments were carried out during the summer period of 1936 and the winter period of 1936-37, and the results were analysed at the National Institute for Research in Dairying. They showed that, in summer, the correlation between the plate count and the reduction test was consistently high, but that in winter it was lower. It was suggested that, in winter, the reducing activity of the organisms found in milk and on utensils was low, and the " potential " reached before the application of the methylene blue test was less than in summer. The predominant types of organisms might also be different under the different temperature and other environmental conditions in winter and in summer. Taking the plate count as a standard of reference, the methylene blue test as now applied was more inaccurate in winter than in summer. Taking the " activity " of the organisms as shown by the methylene blue test as the standard, the plate count gave a less accurate assessment of milk quality in winter than in summer. Both in summer and in winter the percentage of high count samples passing the methylene blue test was lower than the number of low count samples that failed the test. It appeared that, in a series of samples, the methylene blue test instead of the plate count would not injure the producer, and there was no evidence that the methylene blue test is not suited for commercial grading purposes, or for assessing the quality of accredited milk. It appeared desirable, however, to consider introducing some alteration in the method of management of samples prior to the test. As the basis on which advice may be given to the competent milk producer from the competent dairy bacteriologist, according to these experiments, the plate count retains its value.

In continuation of his previous work Professor Wilson has made further investigations into the biological standardisation of methylene blue. Hitherto, so far as is known, the methylene blue imported from Denmark has been standardised quite empirically. At the request of the Ministry of Health, Imperial Chemical Industries, Ltd., prepared a number of different batches of pure methylene blue. These were titrated chemically by the titanous chloride method. They were then sent to the School where they were standardised by a biological method specially worked out for the purpose. The results yielded by the chemical and biological methods of standardisation were almost identical.

A study is being made of the oxygen utilisation capacity of different organisms that are suspected of playing a part in the reduction of methylene blue in milk. The results so far obtained are in general confirmation of those described in Wilson's report. The methylene blue reduction test is clearly influenced to a considerable extent by the growth activity of various types of bacteria, and appears to afford a dynamic picture of the milk rather than a static picture such as is yielded by the plate count.

The nutritive value of raw and pasteurised milk for mice.—Other work carried out under Professor Wilson's direction has included a comparison of the nutritive value of raw and pasteurised milk for mice.* Forty-nine experiments, involving between 2,000 and 3,000 mice, were carried out on two groups of mice fed respectively on raw and on pasteurised milk for 12 weeks. At the conclusion of the experiment the does in each group were mated, and their breeding performance studied. Broadly speaking, it was found that, if the milk was given in inverted tubes, the " raw " mice put on rather more weight than the " pasteurised ", but if it was given in open vessels, the reverse occurred. This finding is not easy to explain, but it does demonstrate that, in biological work of this type, even small technical factors may have a profound influence on the result of the experiment. The general conclusion reached was that any difference which may exist in the nutritive value of raw and pasteurised milk for mice must be very slight, and that no comparative experiment to determine it, carried out on lines similar to those employed in the present work, would probably be worth making on less than 500 to 1,000 mice in each group.

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* "The Nutritive Value of Raw and Pasteurised Milk for Mice". G. S. Wilson and I. Maier. Journal of Dairy Research, Vol. VIII, No. 2, pp. 203–217, June, 1937.

Resistance of mice fed on raw and pasteurised milk to Salmonella infection.—With a view to ascertaining the resistance of mice fed on raw and pasteurised milk to *Salmonella* infection, many of the mice were subsequently injected intraperitoneally, or fed by the mouth, with measured quantities of a culture of *Bact. typhi-murium*—a natural pathogen of the mouse. The animals were observed for 2-4 weeks, and the numbers dying of specific infection determined by bacteriological examination. No significant difference was found in this respect between the "raw" and "pasteurised" groups, in spite of the fact that about 500 animals were included in each group.*

The nutritive value of raw and pasteurised milk for calves.—In collaboration with Professor F. C. Minett and Mr. H. F. Carling, a feeding experiment was carried out on the herd belonging to the Berks and Bucks Joint Sanatorium, Oxon. The herd itself was free from tuberculosis, contagious abortion, and "clinical" mastitis. Alternate calves, as they were born, after being fed for 3½ days on colostrum, were put on to a diet of raw or pasteurised milk, supplemented by hay, and their growth observed for eight weeks. The average increase in weight of the 25 animals in the "raw" group was 53·72 lb. and of the 23 animals in the "pasteurised" group 53·86 lb., or 61·18 and 62·94 per cent. respectively. In their general condition the animals in the two groups were indistinguishable. These results, which have been published,† confirm those obtained by other workers at the two Dairy Research Institutes (see pp. 289 and 295).

Department of Bacteriology and Preventive Medicine, University of Manchester.

A rapid test for detecting tubercle bacilli in milk.—With the aid of a grant from the Milk Marketing Board, an attempt to devise a rapid test for the detection of tubercle bacilli in milk is being carried out under the direction of Professor H. B. Maitland.

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* "The Resistance to Infection with *Bact. typhi-murium* of Mice fed on Raw and Pasteurised Milk". G. S. Wilson. Journal of Dairy Research, Vol. VIII, No. 2, pp. 218–223, June, 1937.

† "The Nutritive Value of Raw and Pasteurised Milk for Calves". G. S. Wilson, F. C. Minett and H. F. Carling. Journal of Hygiene, Vol. XXXVII, No. 2, pp. 243–253, April, 1937.

A method* of microscopic examination of milk from individual cows, for the presence or absence of tubercle bacilli, has been developed, and applied to the examination of milk from farms which have been reported as giving a positive biological test (i.e., by guinea-pig inoculation) for tubercle bacilli in the mixed milk from the farm. In the examination of quarter samples from approximately 950 cows only one instance occurred in which the microscopic finding was not the same as the result from biological examination of the milk or post mortem examination of the cow. No false positive results were obtained.

From a comparison of the results of clinical examination of the cows and the results of microscopical examination of the milk, it would seem that the microscopic test for tubercle bacilli, when it is done on quarter samples from individual cows, is very reliable. The time saved in detecting the infected cow with this method is very great as compared with the biological test. Microscopic examination can be completed in 48 hours, whereas the test on guinea-pigs takes from three to six weeks. Moreover, it is only in about 66 per cent. of cases that the cow responsible for the tubercle bacilli in the milk can be recognised clinically. Thus, in 33 per cent. of cases, after waiting three or six weeks, another visit to the farm has to be made and more samples taken. The microscopic method, therefore, in the hands of a trained and skilful observer, saves time both in examination and in inspection. The farmer gains much from this, especially when the milk from a cow has to be kept from market on account of suspicion of tuberculosis in the udder and after six weeks it is found that the cow has no tubercle bacilli in its milk, but that another cow in the herd is the offender.

The Laboratories of United Dairies, Ltd.

The Company has thirty-four laboratories throughout the country, with a central laboratory at Wood Lane, Shepherd's Bush, and five other laboratories in the London area. In addition to routine examinations, research and investigational work is carried out in consultation with a Research Advisory Council, an independent body of academic distinction and wide experience in the fields of biochemistry, bacteriology, veterinary pathology and public health. At the Central Laboratory there are, in addition to the Chief Chemist, Mr. E. B. Anderson, eight research workers, including section heads, five scientific assistants, and fourteen routine control workers. The practice of the Company is to engage research workers after they have graduated, and then to give them an extra year's training, at the Company's expense, either in biochemistry or in bacteriology, or some other special branch of science.

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* "Rapid Detection of *B. tuberculosis* in Milk". Mary L. Cowan Maitland, "The Lancet", 29. 5. 37, p. 1297, and R. C. Locke, "The Veterinary Record", 1937, Vol. 49, p. 825.

A range of chemical and bacteriological problems of importance is under study at the Central Laboratory. On the chemical side the Company has collaborated with the Water Pollution Research Board of the Department of Scientific and Industrial Research, in the investigation of the problem of the purification of factory effluents. In spite of whey condensing plants, dairy effluents still cause very severe pollution of streams. It is understood that two processes for treating milk factory effluents have now been evolved, which are considered to be satisfactory.

Detergents and disinfectants are being investigated in relation to bottle washing, with a view to determining which detergents provide the maximum killing capacity to organisms remaining in the bottle. Work is proceeding on milk enzymes. Kay's phosphatase test (see p. 290) has been subjected to trial in United Dairies' Laboratories. It had been found to be excellent and all the Company's pasteurising plants are now controlled with this test. Other chemical problems under investigation relate to the oxidation of butter fat, a fault chiefly affecting milk powders, and a study of the methods of manufacture of casein with a view to ascertaining the reasons for the trade opinion that French casein is better than English casein.

On the bacteriological side the problems under study include the bacteriology of low temperature pasteurisation. It was found that milk produced under dirty conditions contained a number of organisms which were not destroyed at the legal pasteurisation temperature. A method is now employed whereby farmers' supplies are checked by test tube pasteurisation, which enables an estimate to be made of the number of organisms left alive. Efforts are made to trace the cause of unusually high counts by inspection of the farmers' utensils. Research on coliform organisms in milk, which reduce the keeping quality, is in progress at every stage of the pasteurising process. The numbers in raw milk are assessed, the possibility of destruction and the degree of survival in the pasteurising process are determined, and the directions and extent of subsequent contamination are studied. In view of the important relationship between the cell content of milk and udder disease, an investigation has been started into the normal and abnormal cell content of milk as delivered to United Dairies. A good deal of information has been collected about the bacteriology of Cheddar cheese and the changes which occur in the ripening process. The object is to discover the reasons for the development of faults and, generally, to improve the quality of factory-made Cheddar cheese. Starters are obtained from an outside source, but are propagated in the Company's own laboratories. The maximum activity of starters, both for cheese and for butter, and the reasons for their failure at certain times, are being studied. Butter defects, such as putrid odours and rancidity due to fat-splitting organisms, are investigated with special reference to the relation of the counts of organisms to the quality of butter.

The Dairy Bacteriological Service.

The scheme for a service of advisory officers in dairy bacteriology began in the year 1924-5 with the appointment of routine analysts to the School of Agriculture, Cambridge, the South-Eastern Agricultural College, Wye, and Bristol University. Two years later the scheme had been extended to seven other centres, namely, Aberystwyth, Bangor, Newcastle, Seale Hayne College, Harper Adams Agricultural College, Reading, and the Midland Agricultural College. In 1931-2 the grants from the Development Fund in aid of dairy bacteriological work were consolidated with the grants made to the various centres for other advisory work. At Leeds, Mr. C. H. Chalmers, a member of the staff of the Department of Agriculture, assists in the scheme, but his salary is paid entirely by the Department.

In a memorandum supplied to the Dairying Committee by the Ministry of Agriculture and Fisheries it was pointed out that the dairy bacteriologists had become of definite value in dealing with matters relating to clean milk production and that County staffs would find it difficult to carry out many of their investigations into the causes of impure milk without the co-operation of the dairy bacteriologists. The latter, moreover, were carrying out much original investigation of local significance, and in certain cases were tackling more fundamental problems of general application. The Ministry thought it important, in considering the future of the scheme, to bear in mind the increasing public interest in the question of a clean milk supply, which will enhance the usefulness of a bacteriological service;

and it was felt that the replacement of the plate count by the methylene blue reduction test in the examination of Tuberculin Tested and Accredited milks for grading purposes should make the bacteriological testing service not of less, but of greater importance from the advisory standpoint. While it might be expected that County staffs would themselves take over milk testing work, the reduction test could give no help in establishing the causes of dirty milk and it might be assumed that the help of the dairy bacteriologist would be sought to an increasing degree as a result of the change.

The Dairying Committee's survey, in the course of which the opportunity was taken of interviewing all the dairy bacteriologists, enabled a detailed idea to be formed of the type of problem in the advisory and investigational field, as distinct from that of routine determinations, which the bacteriologists are called upon to undertake. Work in this field covers a fairly similar range of problems throughout the country. Much help and advice is given to milk producers desirous of qualifying for Accredited and Tuberculin Tested licences, visits are made to farms where high bacterial counts, coliform contamination, and poor keeping quality are sources of trouble, and studies are made of the efficiency of various methods of steam sterilisation of milking machine units and dairy utensils under farm conditions. Numerous milk samples are examined with a view to identifying and tracing the cause of defects, such as taints and ropiness. The type and source of thermophilic organisms found in raw and pasteurised milk are studied, and reasons are sought for the troublesome incidence in certain districts of deficiencies of butter fat and non-fatty solids in milk. At Cambridge, work has been done on the experimental feeding of different oils as a means of altering the butter fat content of milk. The problem of slow working in cheese making and its relation to starter vitality and the quality of the cheese milk is receiving attention at Bristol and Harper Adams College. At Aberystwyth, 600 samples of milk were examined during 1935-6 for tubercle and abortion organisms both in bulk herd milk and in samples from individual cows, while at Reading, in the same year, 1,914 samples were examined for tubercle organisms. All the centres carry out examinations of water supplies on farms and in factories, and all centres have undertaken special work on the methylene blue reduction test, especially from the point of view of its correlation with the plate count, coliform and keeping quality tests (see p. 311). Most of the dairy bacteriologists have been concerned with work arising from the detection and control of mastitis. At Cambridge, Mr. Oxley is co-operating with Dr. Spooner of the Department of Medical Pathology, in an attempt to isolate different strains of haemolytic streptococci from the milk of individual cows suffering from mastitis. At Bristol, Mr. Egdell is concentrating on herds in which mastitis is widespread and, in conjunction with the Veterinary Investigation Officer, who is in touch with Professor Minett, efforts are being made to find remedies. The value of udder injections is being investigated.

The effect of the Accredited Producers' Scheme and the Milk (Special Designations) Order, 1936, upon the manner in which designated milk samples are tested is not uniform throughout the country. In Wales the tendency seems to be against the establishment of special County laboratories for this work, and in favour of reliance upon the services of the dairy bacteriologists. In some of the counties of England, however, particularly in the areas served by Cambridge, the Midland and Wye Colleges, and King's College, Newcastle-upon-Tyne, there appears to be a definite movement towards the entrusting of the routine part of the work to the County staffs, the dairy bacteriologists being brought into consultation only in an advisory capacity in connection with official samples which show abnormal results. Routine testing has hitherto been a mainstay of the dairy bacteriological service; it earned income and it was the principal source of advisory work. Now clean milk production has passed from an educational ideal as expressed in clean milk competitions to an administrative requirement. In these changed circumstances it is not unnatural that the duties of testing designated milks should be taken over by the County Authorities. The consequential reduction of the income from fees of some of the dairy bacteriological centres is unfortunate, from the financial point of view at least, but it is inevitable, and the case for the continuance of the service at its present strength now seems to rest mainly upon the need for advisory and investigational work, which it is held that the dairy bacteriologists can best undertake.

It appeared to the Dairying Committee that there should be sufficient work in this field for the dairy bacteriologist, since he should be able to count upon the reference to him of " advisory " samples from the County Agricultural Education staffs in addition to the problems of individual farmers. Although it is clear that the County staffs, as distinct from the farming community, are making some use of the dairy bacteriologists in seeking their advice on abnormal samples, it was felt that a decision regarding the future of the service must be based upon a more definite understanding of the intentions of the County Authorities. In some cases at present the amount of work which the dairy bacteriologist may derive from County Authorities seems to be a matter of chance. The degree of co-operation often varies from county to county within each Province, and what is wanted is some clearer indication than is available at present as to whether, for example, the County Councils have it in mind ultimately to undertake the advisory as well as the routine work. There is a feeling among the bacteriologists of lack of cohesion and of the need for a single milk service which would co-ordinate all milk activities. It is claimed that, because the administrative staff can only devote a fraction of its time to milk work, even though it possesses the compulsory powers, and because the dairy bacteriologist approaches dairy problems with a background of experience and with specialised laboratory methods and is the only person who devotes the whole of his time to the subject, the dairy bacteriologist should find a place for work in a clearly defined field uncontested by other interests and in harmony with a general scheme.

In spite of this disorganisation in the work of the dairy bacteriologists, it is believed that the future tendency will be for farmers to make more use of bacteriological services than before. The higher the standard called for by Public Health Authorities, the greater the risk of milk failing to conform to that standard, and the more often will advice be required. Before advice can be given it will frequently be necessary to make a bacteriological examination of the milk and, thus, although county laboratories will make the analyses required for " inspection " purposes, analyses both of the advisory (i.e., investigational) and routine types will be demanded. The standard of the service which the dairy bacteriologists offer has, naturally, improved greatly as a result of the experience now gained over a number of years in their particular provinces. They have increased their knowledge of local problems, technique has been advanced, valuable contacts have been made with the County Authorities, and confidence in their work has been established among the farming community. To dispense with these advantages now, after much money has been spent in securing them, would require strong justification, for it might result in a quite serious check to the educational influence which the service exerts upon the dairy farmer; and, because this influence is free from any element of compulsion, it might not be replaceable by other measures which are operated from administrative necessity.

Now is the time when the position and functions of the dairy bacteriologists should be defined in relation to those of the public health and dairying staffs of Local Authorities. As such definition depends very largely upon the attitude of Local Authorities and upon their view as to whether problems (and in some cases routine examination of samples as well) can usefully be referred to the dairy bacteriologists, the Dairying Committee recommended that the Ministry of Agriculture and Fisheries should endeavour to arrive at an understanding with the responsible Authorities in the Counties as to the quantity and nature of milk work, including fee-paid work, which they are prepared to agree should be dealt with by the provincial dairy bacteriologists. Until information of this kind of a more definitive nature is available, it is not possible to say either that the case for the continuance of the service as a whole is proved, or whether in certain Provinces the services now being provided by the County staffs, because of present-day administrative and educational requirements, would permit of the services of some of the dairy bacteriologists being discontinued without serious injury to the dairy industry. The trend may well be in the direction of making an increasing use of the services of the dairy bacteriologists. How this is to be arranged will depend upon the action of County Authorities. There are, moreover, other uncertain elements which support a delaying policy at the present time. For example, the effect upon the dairy bacteriologists of the programme of the Ministry of Agriculture in the matter of animal disease eradication through a centralised veterinary service would need to be ascertained, as also would the effect of any national movement on the part of the Ministry of Health in the direction of the compulsory pasteurisation of milk.

IX.—AGRICULTURAL ENGINEERING

Institute for Research in Agricultural Engineering, Oxford.

The Institute for Research in Agricultural Engineering at Oxford is the only Institution of its kind in the country. Its function may be broadly defined as fostering by research, by testing and by practical demonstration the improved application of power to agriculture. Since its earliest days the Institute has been called upon to carry out tests of agricultural appliances under the Testing Scheme of the Ministry of Agriculture and Fisheries, but these tests have never been very numerous.

At the beginning of the period covered by the present Report, the Institute was organised in three main sections dealing with power and power units, implements and cultivation and the survey of mechanised farms.

As mentioned in the last Report, a Sub-Committee of the Council visited the Institute in 1934. In reporting to the Council, this Sub-Committee referred to a decision taken at the end of the previous year, to continue the Institute's work at Oxford for a further period of three years, and stated that they had in consequence confined themselves to an examination of the work in progress at the Institute and to making recommendations regarding the funds needed to meet its cost. The Sub-Committee were glad to be able to report that more attention was being given at the Institute to the practical side of agricultural engineering than in 1932, when the Institute had previously been visited by a Committee of the Council. To carry out the programme which the Sub-Committee considered to be desirable, certain additions to the grant were recommended, and the Council, after considering the Sub-Committee's report, recommended that an addition of about £500 should be made to the grant to be paid to the Institute during each of the following three years.

Later in the same year, when the estimates of the Institute came before the Development Commissioners, the Commissioners appointed a Committee to visit the Institute and to discuss its financial requirements in relation to the programme and staff. This Committee were satisfied that progress was being made, though they considered that the programme of the Institute was still too diffuse. They recommended that the technical staff of the Institute should be so constituted as to enable the Institute to investigate only those agricultural problems which experience in advisory work indicated were of agricultural importance and which were also directly dependent for their elucidation on the services of trained engineers. A block grant of £10,500 per annum was recommended for the year 1934 and similar grants for the two succeeding years, subject to the usual annual review of estimates. It was recognised, however, that additional funds might be required for the purchase of foreign machinery or implements and for any travelling abroad, and that application to the Ministry of Agriculture and Fisheries for special grants for these purposes might be necessary. These recommendations were adopted by the Development Commissioners and grants of £10,500 were subsequently sanctioned by the Treasury for each of the three years of the period which terminated on the 30th September, 1937.

During 1936 two long-term investigations were concluded at the Institute. The first of these was a study of the dynamics of tractors and tractor wheels under the direction of Mr. S. J. Wright, the Deputy Director, who subsequently undertook, with other workers, the investigation of discrepancies between the rated and actual performance of tractors under field conditions. The rated performance of a tractor is 75 per cent. of its maximum power. The actual average performance of tractors is about 70 per cent. of the rated load. This implies that under field conditions the average tractor is working at about half its maximum load.

During 1937, research on tractors was confined to two specific problems, the control of crank case dilution and the efficiency of tractor loading in the field. These problems are related, because under-loading results in low temperature running and this in turn is a primary cause of dilution. Tests of a standard tractor under controlled conditions showed that by maintaining the temperature of the cooling water at not less than 90° Centigrade the percentage dilution of lubricating oil could be greatly reduced. A general tendency for tractors to be under-loaded in practice was disclosed by a dynamometric study of the work of 20 machines selected at random in various parts of the country. This indicated that the average loading efficiency was only about 70 per cent. A paper describing this work and pointing out its bearing on tractor economy in practice was read at the Mechanised Farming Conference in January, 1937, to which reference is made below.

The second investigation, which concerned the effectiveness of mole drains drawn under various conditions, had been in progress on a field of heavy clay for three years. This work was related mainly to the development of apparatus for making full records for drainage outflows in the field and did not aim specifically at obtaining actual measurements for research purposes. In the course of development and control of automatic metres for flows up to 240 gallons an hour numerous records were, however, made and analysed. These may be of value in checking the theoretical predictions of other workers in this subject.

Work on grassland, which has been in progress for some years, has indicated that the rejuvenation of rough pasture is dependent on the number of horse-power hours per acre of work put into the surface of the turf, irrespective, within limits, of the design of the implement used, but that, in practice, the main factor governing the performance of an implement is the proportion of time necessarily expended in the frequent cleaning of the tines. An implement has now been found in which the time spent on cleaning is reduced to a very small amount.

In connection with work on the production of high moisture content hay, conditions have been defined in which the upper limit of moisture content attained in previous years could be substantially raised. It was shown in 1936 that even in a wet season there are striking advantages to be gained by tedding the swath immediately after cutting. A special machine combining the two mechanisms was developed in the Institute's workshops and worked satisfactorily. Some further work on hay baling has indicated that hay can be safely baled at moisture contents well above those considered safe for stacking, and that a higher quality final product would generally result. Particularly with wire-tied bales, however, there are very definite limits to the bale density for a given moisture content, if the risk of mould formation is to be avoided.

Another investigation which may be mentioned was an examination of electric leakage on farm installations. The conditions existing on a large number of commercial farms have been studied and the performance of different earth-leakage circuit-breakers has been examined. Points which have received special consideration have been the likelihood of danger arising in practice from uncleared leakages, the conditions set up when such leakages occur and the efficiency of various means of protection.

During the period under review a permanent scheme for the testing of agricultural tractors under practical conditions was drawn up by the Royal Agricultural Society, with the approval of the Machinery Testing Committee of the Ministry of Agriculture and Fisheries. The Institute designed all the necessary apparatus and carried out tests on 10 tractors under the scheme.

Conferences on mechanised farming were arranged at Oxford during January in 1936 and 1937 in co-operation with the School of Rural Economy and the Agricultural Economics Research Institute. At the first conference the main subjects dealt with were the mechanisation of arable farming, problems of livestock and grassland management, and harvesting on medium-sized farms. At the second conference the main subjects discussed were cultivations and grass conservation. The conferences were well attended and the proceedings of both conferences have been published.

In 1937 a further review of the organisation and activities of the Institute fell due and early in the year the University of Oxford appointed a Committee to enquire into the work and organisation of the Institute and to report to the Hebdomadal Council as to whether any changes were desirable. Representatives of the Agricultural Research Council gave evidence before this Committee.

Following this enquiry the University came to the conclusion that the work of the Institute should be continued at Oxford on a modified scale and for this purpose made application for a block grant of about £7,800 per annum to cover the cost of maintaining the Institute for a further three years ending on the 30th September, 1940. The application represented a reduction of nearly £3,000 per annum on the existing cost of maintaining the Institute, provision being made in the new estimates only for the essentials required for work on the new programme proposed.

The new programme is not intended to cover the whole field of agricultural engineering, no provision being made, for example, for work on drainage, land reclamation, grassland improvement or electrical development. The programme deals mainly with problems related to the use of tractors and tractor implements in cultivation, transport and harvesting, as these problems appear to offer the most fruitful field of work at the present time. The use of tractors is extending so rapidly that new problems requiring the services of a research staff are continually arising and, moreover, almost all present day implement development is associated with tractor use.

The new programme of work may be divided into five categories, viz.:—dynamometry, tractor design, particularly in connection with tractor wheels and crank case dilution, testing of agricultural appliances, tractor utilisation and the continuation of the survey of mechanised farms.

In submitting the application for grants to continue the work of the Institute on the new basis, the University expressed the view that Oxford provided in its School of Rural Economy and the farm at Long Wittenham, with which the School was associated, and in the Institute for Research in Agricultural Economics, an ideal background for agricultural engineering research. It was proposed that arrangements should be made to transfer the field station of the Institute for Research in Agricultural Engineering from Benson to the Long Wittenham farm, or to some site in close proximity to it. It was pointed out also that, as the Agricultural Engineering Institute was frequently concerned in problems governed by purely agricultural considerations, its work would in future be carried out in close co-operation with the Professor of Rural Economy. The Institute would, in fact, be prepared to undertake the engineering side of any work which the School of Rural Economy might initiate. It was expected that the result of these proposals would be a closer association between testing, advisory work and research work at the Institute.

The new programme was referred by the Council to a Committee which recommended that, in accordance with the wishes of the University, the Institute should be maintained at Oxford. The Committee were gratified to learn that closer contact and co-operation would be maintained between the Institute, the School of Rural Economy and the Institute for Research in Agricultural Economics and they noted with satisfaction that joint work would be undertaken by the two Institutes. They strongly supported the proposed arrangement for the joint use of the Long Wittenham farm, owned by St. John's College and situated at a distance of about 10 miles from Oxford, where the experimental work of the Agricultural Engineering Institute could in future be carried out. There is at this farm a variety of soils, so that results of experiments undertaken here can be used as a standard by which measurements on other land can be expressed.

Acceptance of all the proposals made by the University was recommended, subject, however, to a further review in 1940. The Committee expressed the hope that the Institute would find it possible to deal with problems of machinery on farms of all sizes and types and that it might also be possible for research on problems connected with the drying of grass and other fodder crops to be resumed at an early date.

The recommendations of the Committee were adopted by the Council and were accepted by the Development Commissioners and by the Treasury and a grant of £7,800 for the maintenance of the Institute during the year commencing 1st October, 1937, has since been sanctioned.

The Director's term of office expired in September, 1937, and he did not seek re-appointment. Mr. S. J. Wright, who was formerly Assistant Director of the Institute, has since succeeded to the Directorship.

GRASS DRYING.

The Council's Committee on the Preservation of Grass and other Fodder Crops, as stated in the previous Report, surveyed the situation regarding the processes for the preservation of young grass, and, in November 1935, issued its first report; the demand for that report indicated a wide interest in this subject. Particular attention was given to conservation by artificial drying. The Committee had made a survey of farm-scale driers available at that time, and, with the aid of a grant of £1,000 from the Council, had installed a Ransome-Davies drier, with a Wilder Cutlift, at the Hannah Dairy Research Institute, with the idea of testing the drier and of completing an investigation on the relative nutrient values of spring and autumn grass. Drying operations were begun there in May, 1935.

The situation as regards grass drying in 1935 gave reasons for supposing that, in the following year, interesting developments could be expected in this new method of preservation. Nearly a dozen farm-scale driers were in operation, including four that had been installed at aerodromes, and a number of experimental models—among them the forerunner of the Billingham, which was to be produced for sale in the autumn of 1935. The Committee decided to continue its investigation on conservation by artificial drying, and appointed a Crop Drying Investigator for visiting grass drying centres in 1936 in order to collect information. Accordingly Mr. E. J. Roberts was seconded from the University College of North Wales, Bangor, for this purpose, and the results of his survey were published by the Council in May, 1937, as Agricultural Research Council Report Series No. 2. This appointment was subsequently renewed to September, 1938. It had been decided in the meantime, however, that the Crop Drying Investigator should not continue an individual survey, as in 1936, but should act as co-ordinating officer for grass drying investigations, carried out under the auspices of the Ministry of Agriculture and Fisheries, by County Organisers, and the staffs of the various Colleges and Research Institutions. A small committee, formed from the Committee on the Preservation of Grass and other Fodder Crops, and the Ministry of Agriculture and Fisheries, drew up a schedule of information required on grass drying, and this was circulated to the above organisations. The results of the various enquiries carried out in 1937 have not been received up to the present, and this report is therefore confined mainly to the results of the survey carried out during the previous year.

The number of grass drying centres rose from less than a dozen in 1935 to nearly 50 at the end of the following year; all but five of these being farms. This rate of progress was not maintained through 1937, though the number of centres then rose to a total of about 75. Between 5,000 and 6,000 tons of dried grass were produced by the farm driers in 1936, and about the same quantity of dried lucerne and dried grass was made at the two factory installations of Messrs. British Crop Driers, Ltd., and Messrs. "R.G." Foods, Ltd. Again, while only one make of grass drier could be purchased by the farmer in 1935, six were available in the following year. Grass drying in Great Britain is characterized by the large proportion of farm-scale driers, while abroad artificial drying is carried out almost entirely in large-scale factory units. It may be mentioned that the Committee responsible for this investigation has been, from the start, more interested in the type of drier that individual farmers could operate than in the factory machine.

The driers were, for the most part, owned by well-to-do people, the capital necessary having put driers beyond the means of the average farmer. Drying was carried out mostly on dairy farms. Many of the producers who did not intend originally to produce for sale were tempted by the high prices of dried grass to sell a portion of their output.

Quality of products.—It became evident, early in the survey in 1936, that only about a quarter of the total product was of the quality envisaged by Wood and Woodman, the early Cambridge investigators, the bulk of the product having reached the stemmy condition before it was mown. The high rate of growth of pasture in the spring flush, when, in such seasons as that of 1936, it may make 70 per cent. of the year's growth in a month, and the low outputs of the driers, were responsible for this failure.

Grass drying machines.—The types of driers that were used in 1936 and 1937 may be classified as follows:—

(I) Tray driers, with trays:
  (*a*) Movable, Billingham drier;

(*b*) Fixed, Curtis-Hatherop drier. It may be mentioned that the tray type of drier is favoured by those who hold that hand tedding is essential for a uniformly dried product.

(II) Endless belt driers, with different arrangements of air currents, etc. Three of this type were produced, viz., Ransome-Davies, Petrie & McNaught (P. & M.), and the Mobile.

(III) Rotary drier, with a revolving drum. Kaloroil double-hopper.

(IV) Pneumatic driers. The grass is dried as it is carried along in the furnace gases.

(*a*) The Greenwell.
(*b*) The Harvest Saver.

(V) Steam drier

In the 1936 season the Billingham drier, which was sold in two sizes, outnumbered those of all other makes together, but its production has now ceased. This drier, which was placed on the market just before the publication of the first Report of the Committee, has been briefly described in that report. The furnace, as originally built, was defective, and many specimens had to be relined before the end of the season. A modification, by which water was led to the grate bars, caused considerable improvement. The larger Billingham drier had a rated output of 3½ cwt. of dried grass per hour from fresh grass containing 78 per cent. of moisture. This model cost £750 complete with electric motor, but without a baler. Thirty-two were in operation in 1937.

The Curtis-Hatherop is a two-stage tray drier, differing from the Billingham in that the trays are fixed, hauling mechanism and extended platforms being thus dispensed with. Instead of a drying chamber, a light movable hood is used above the tray of half-dried grass, in order to lead back the gases for recirculation; the drying current that has passed through the tray of fresh grass is not used again. Compared with the Billingham, this drier has the advantage that there is loss of neither heat nor time at the change-over to the duplicate set of trays. Improvements incorporated in this machine during the 1937 season include an improved fan, and a hurdle over both the dry and half-dry trays, thus minimizing the loss of heat through " blow-holes ". The drier has a relatively high output per unit of capital cost. Ten were in operation at the end of 1936.

The Ransome-Davies drier, as described in the first Report, utilises a moving band of ladder bars, carried on sprocket chains, which conveys the grass over a perforated floor. There are two separate temperature stages, the drying current being at 300° F. under the fresh grass end of the mat, and at 220° F. at the outlet end; the possibilities of scorching are thus reduced. The principle of re-circulation is embodied in this machine, the drying current from the outlet end of the drier being taken back to the furnace to be used again. The conveyor type of drier has the advantage over the tray drier that the heavy, partially dried grass does not require handling. The contest between the tray and conveyor type of drier was still undecided at the end of 1937, after two seasons of operation at various farms, and it is probable that both types will continue to have their advocates. The tray drier will find support from those who favour hand tedding and a cheap machine with few moving parts, while the endless belt type has obvious advantages, especially with heavy material like fresh grass. A few refinements have been added to the Ransome-Davies drier since the 1936 season. A device for packing the grass evenly on the belt can be fixed, and a hood, with an outlet to the air, has been built over the inlet end of the drier in order to lead away the vapour. This is an improvement, both in increasing the comfort of the operators, and in diminishing the damage from corrosion. A season of grass drying has demonstrated the heavy wear and tear of metal shedding, etc., caused by the escaping vapour; indeed, the makers of another type of drier are now using asbestos sheeting for roofing the shed. Twelve farm-scale models of the Ransome-Davies drier were in operation by the end of the 1937 season.

The P and M (Petrie and McNaught) drier differs from the Ransome-Davies in that the drying current enters the mattress of grass from above as well as from below. Again, the temperature is thermostatically controlled in the P and M, there being a forced draught fan to supply air to the firegrate, the amount of air so supplied being regulated by a thermostat placed in the drier. This machine cost £1,350, excluding power units, but including a covering for furnace and drier, and is guaranteed to evaporate 1,800 lb. of water per hour. Five farm-size models of this make were in operation by the end of 1937.

The Mobile drier differs from the two previous, not only in being portable, but also in that it has six superposed conveyors, instead of one long one. The grass cascades from one conveyor on to the one below, thus assisting regular and even drying. This machine also differs from others in that it employs radiant heat, hot panels being situated between the conveyors. Furnace gas, with an inlet temperature of 300° F., circulates through the panels, and escapes through small holes in their under surfaces; the escaping current carries away the water vapour formed as a result of the heating of the grass by the hot panels. Temperatures are recorded electrically at the inlet and above the grass on the lowest belt, the extent of the difference indicating the degree of dryness. The speed of the belts is easily varied by reduction gear, so that incomplete or over-drying can be readily corrected. This drier costs £950, complete except for the power unit. Output tests, etc., have been carried out in 1937, and the results will soon be available for publication. Two machines of this type were in operation by the end of that year.

The Kaloroil double-hopper drier operates on the rotary principle, and is a two-stage machine. While the final drying stage is performed in a slowly revolving drum, the exhaust gases pass through a charge of grass that is in the hopper, awaiting its turn to enter the drum; the drying current thus passes through two lots of grass before escaping into the open air. Continuity of drying is secured by having the hopper in two parts, with a charge of grass in each. Thus when the drum has to be emptied of dried grass, the drying current is turned direct from the furnace to one section of the hopper. In the course of the 1937 season the Kaloroil was improved by embodying in it the principle of re-circulation, the drying current being used again in the later stages of drying. It may be mentioned that this drier, though built primarily for burning fuel oil, can be supplied with a furnace for coke, anthracite, or coal. Twelve were in operation by the end of 1937.

Two pneumatic driers were in operation, that designed by Sir Bernard Greenwell, which has worked for two seasons, and the "Harvest Saver", introduced towards the end of the 1937 grass season. One model of the former, and four of the latter, have been in use. Pneumatic driers operate on the principle of drying the herbage by carrying it along in the furnace gases; the grass is thus in suspension, and all surfaces are exposed to the drying current. The temperature is much higher than in ordinary driers, being about 800-1,200° F. at the inlet, so that drying is accomplished in a few seconds. The high moisture content of the grass, and the carbon dioxide in the furnace gases prevent the herbage from taking fire. In the Greenwell drier, the furnace gases, with the grass in suspension, are sucked through long piping, while, in the Harvest Saver, the drying current is drawn between concentric drums.

Steam heated piping has been embodied in two driers that were operated in 1937, and has been included in the design of two others, contemplated for 1938. Only one, the Kilmartin, will be mentioned, since it has been the only steam operated drier actually available for purchase up to the present. In the

Kilmartin drier, two models of which have been in operation, steam from a large boiler is passed through a cone-shaped coil of piping. The fresh grass is stacked around the coil and air is blown, by means of a fan, from the inside of the coil, outwards, through the stacked-up grass. After about seven hours, it is stated that the stack is dry.

Finally, it may be mentioned that grass may be dried in malt kilns and in hop kilns. Disused hop kilns can be used, the single floor being replaced by two superposed floors of wire mesh. No elaborate machine is essential, and the drying temperature is not a matter of great importance so long as the product is removed as soon as it is dry. The higher the drying temperature, the greater the precautions necessary for ensuring that the herbage is not exposed to the drying current after it has become dry.

Three factories were in operation during 1937 for drying lucerne and grass. The largest, that of Messrs. British Crop Driers, Ltd., King's Lynn, has an annual output of about 5,000 tons of dried lucerne, which is produced from about 2,000 acres of inferior land. This is a commendable venture, since it accomplishes, as a commercial proposition, the production of heavy yields of high grade animal food from land that many would regard as too poor for farming. It is interesting to know that this company has arranged for expansion before the 1938 season.

Messrs. "R.G." Foods (Parent) Co., Ltd., approach the problem of grass conservation from a new angle. The herbage is steeped for about a minute in a grass extract, obtained from previous steeping, and maintained at just under boiling point, after which it is pressed between iron rollers so that it contains only 60 per cent. of moisture. The grass may then be dried, or ensiled, or compressed into metal containers ready for sale; the extracted grass does not undergo loss on storage, the process of steeping having destroyed the ferments. The grass treated in this way has an excellent colour, and chemical analysis shows it to be of high quality. No information is available as to the removal of constituents in the process of steeping and rolling. A saturated extract of the grass would not dissolve any of the constituents in the herbage, but some of these may be squeezed out under the rollers. Two factories using this process are in operation, one in Derbyshire and the other in Northumberland.

Foreign grass driers.—The Crop Drying Investigator had an opportunity of making short tours in Sweden, Denmark and

Germany for the purpose of inspecting machines and of discussing drying with farmers and manufacturers. Artificial drying abroad is mostly confined to the large factory-size unit, and the material is chaffed before entering the drier. The Pehrson and Rema-Rosin are high-temperature machines, giving good results on the Continent with both grass and sugar-beet tops. The Edholm is a low temperature drier suitable for the individual farmer. A current of warm air, produced by a fan and a radiator formed of steam or hot water pipes, is passed through the grass, which is contained in vertical racks. The process is made continuous by drawing out the grass when dry from the lower end of the racks, and putting in fresh grass at the top. The artificial drying of green fodder crops is not carried out to a greater extent in the other European countries than in Britain; the drying of beet tops, and of whole beet that is surplus to the requirements of the sugar industry, appeared to be considered of importance in Germany.

Furnaces.—The furnace is a very important part of a grass drier, and mention should be made of the fact that considerable attention has been given to furnace design, not only by makers of driers, but also by the technical staff of the London and Counties Coke Association, and of the Amalgamated Anthracite Collieries, Limited. Manufacturers and farmers can be supplied, free of charge, with designs of furnaces of different capacities suitable for coke, coal or anthracite.

Efficiency of driers.—The efficiencies of the Ransome-Davies and P. and M. driers installed at the Hannah Dairy Research Institute were subjected to full engineering tests by the staff of the Royal Technical College, Glasgow. The former was tested in 1935, and, following certain modifications, again in 1936; the latter was tested in 1936. The results of these tests have not been published, because the machines have been modified since the tests were carried out. The Committee considered that these engineering tests should serve as models for others that may be carried out in the future.

The over-all efficiency of driers can, for practical purposes, be easily tested by weighing the fuel, the fresh grass and the dried grass produced from it, and thus finding the weight of water evaporated by a given weight of coke, coal, or oil. To complete the picture, the amount of power used by the fans should be taken into account, since some systems of drying have the advantage of low power consumption. Such tests are not likely to give reliable data if carried out for periods of less than one day duration. It may be added that the educational value of such tests is increased if records are kept of time taken to get up heat in the morning, drying temperatures, and of loss of time through various causes. Simple tests of this nature should be carried out at frequent intervals by those in charge of grass driers, since it checks the efficiency of the operators as well as of the machine.

Several such tests were made on farms in 1936 and 1937, those in the latter year, the results of which have not yet been received, having been done under the supervision of County Organisers or officers of the Advisory Centres or Institutes. Three makes of coke-burning driers, one oil-fired, and one converted hop-kiln were used in the 1936 tests, seven farms having been included; at one farm the tests extended over several weeks. The fuel ratios, or the amounts of water evaporated by 1 cwt. of fuel, varied from 3·5 to 5·3 in the coke-fired machines. An efficient drier of this size, properly worked, should evaporate about 7 cwt. water with 1 cwt. coke. The lower efficiencies were obtained on farms where drying operations were stopped for meals, etc. The oil-fired machine evaporated 96 lb. of water with one gallon of fuel oil, and, in the converted hop-kiln, 84 lb. of water was removed by that quantity of fuel. The units of electricity required for working the fan and baling varied from 20 to 54 per ton of water evaporated, the former having been obtained with a moving band drier (Ransome-Davies), and the latter with a two-stage tray drier (Billingham), in which the drying current is drawn through two layers of grass. It will be interesting to discover if the results for 1937 reveal improvement in the efficient use of fuel and power.

Arrangements have been made whereby manufacturers will, in future, be given facilities for having full engineering tests of their driers carried out by the staff of the Royal Technical College, Glasgow. The advantages of having these tests performed under standard conditions, by the same staff of experts, are obvious. Manufacturers desiring full engineering tests are recommended, before such tests are arranged, to submit drawings of their driers to the College; points of difficulty that are likely to arise can thus be discussed, and perhaps be corrected, in some instances, before the test. A manufacturer not wishing to have the full test can have the drier tested simply for output and fuel ratio, and for checking claims made on its behalf.

Output tests.—The low output of the farm driers was the most disappointing feature of grass drying in 1936. The outputs were considerably lower than expected, and this failure resulted in the areas of grassland that were reserved for the driers proving too large. The high rate of growth in the flush period, together with the high water content of the herbage in wet weather, made the disadvantages of a low rate of throughput very obvious. The grass passes quickly from the short leafy condition to the stemmy stage, when it is too mature to make high quality dried grass, and with outputs of only about 2 cwt. per hour, it can be realized that only a small area of land can be coped with if the quality of the product is to be maintained.

The output of dried grass per hour varies with the moisture content of the fresh herbage, the extent of the variation surprising those who have not given the matter much thought. Thus, starting with fresh herbage containing 66 per cent. of water, a drier capable of evaporating 12·25 cwt. of water per hour would roughly produce 6·12 cwt. of dried grass in that time; with 80 per cent. of water, a very common proportion, the output would be reduced to 3·06 cwt. per hour.

Records of actual output over the whole season of 1936 were available from ten farms, and these varied from 1·31 cwt. to 2·68 cwt. per hour, both having been obtained from the larger Billingham model. The highest hourly output was on a farm where drying was carried out continuously, day and night, and where the season's production of dried grass amounted to 320 tons. These figures show up the weakest feature of grass drying. Outputs of 2½ cwt. an hour are too small to attract the large farmer; the capital that was required to obtain that rate of production in 1936, was, however, one that only a large farm could support. Improvement has since been effected in increasing the output relative to capital, but data are not available up to the time of writing. It may be remarked that the above records of output do not give a full picture of the capacities of the driers, since the proportion of water in the herbage was not known. The grass season of 1936 was unusually wet, and the conditions affecting the throughput of grass driers are not often likely to be more severe.

Wilting.—Wilting, or partial field drying, offers, under certain conditions, the most hopeful avenue for increasing the output of grass driers and decreasing drying costs. Instead of hauling the herbage to the drier immediately it is mown, it is allowed to remain in the swath, or in small heaps, for varying lengths of time. Wilting has not been recommended where the dried herbage is required for incorporating in foods for pigs and poultry, for the buyers then value it mostly for its high carotene content.* When the product, however, is required for use on the farm, where the need for carotene is not so great as when stock is reared entirely indoors, wilting might be justified if a machine were available that was capable of picking-up short grass off the ground. The Wilder " Cutlift " enables the short grass to be mown, and elevated to a trailer in one operation, and wilting has the disadvantage that, up to the present, it necessitates giving up this very cheap method of collection. Other disadvantages of this method of drying have been discussed in the Report (see p. 326).

Much research is, however, necessary before the merits and disadvantages of partial field drying can be assessed. Thus, it is known that, when grass is made into hay in the ordinary way, a loss in nutrient value of about 12 per cent. may occur before it leaves the field, even when there is no rain; this loss is due to the continuation of respiration after the herbage has been mown, and to mechanical losses. If grass is wilted for some hours, it is reasonable to expect that a certain proportion of the above loss is suffered in addition to some loss of carotene, and, furthermore, that a higher rate of loss might occur with young grass than with herbage at the age usually cut for hay. Very little knowledge is available on the changes that occur when a green herbage plant is cut at an immature stage, and allowed to dry. It is possible that, with young grass, which may contain at least a third of its dry weight of cold-water-soluble fructosan, wilting may be wasteful.

The 1936 season did not present a good opportunity for showing the full effect of wilting in reducing fuel and power costs; the large number of days on which rain fell resulted in the wilted material often having to be hauled to the drier when containing as high a proportion of water as it had at the time of cutting. Taking the average costs for five farms on which wilting was practised, and of seven where the grass was dried without wilting, the average cost of coke (or fuel oil) and electricity per ton of dried grass amounted to 26s. 2d. in the former, and 38s. 0d. in the latter, the saving through wilting having amounted to 11s. 10d. per ton in a year that was unfavourable for this process. But it must be remembered that the increased cost of collection and the loss of some carotene, and possibly of other substances of nutritive value, have to be balanced against that saving.

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* Recent research, nearing publication, indicates, however, that wilting for one, or even two, days may be practised without a serious loss of carotene.

Costs of Production.—An opportunity was presented in the course of the survey by the Crop Drying Investigator of obtaining records of the costs of production from twelve farms. The extra capital that was needed for drying varied, in that year from £300 to £1,450, including the baler, shedding for drier, etc., but excluding field equipment and a shed for storing the product. The cost of producing one ton of dried grass at the twelve centres averaged £5 17s. 5d.; this compares with £5 18s. 6d., obtained by Dixey and Askew, of the Agricultural Economics Research Institute, Oxford. The costs varied from £4 8s. 0d. to £7 0s. 0d. a ton. No charges were made for interest on capital nor for overheads. Of the average total cost, wages accounted for 33·3 per cent., fuel for 20·5 per cent., depreciation for 13·8 per cent., and manures for 10·0 per cent.

An examination of the costs shows that a spectacular reduction cannot be expected in any one item. Increased output and decreased capital cost would cause a reduction in wages and in depreciation, while higher efficiency in driers, raising the fuel ratio from five to seven, would reduce the cost of fuel and power. A survey of the costs of producing dried grass in 1937 has been carried out from the Institute for Research in Agricultural Economics, Oxford, the Hannah Dairy Research Institute, and by Advisory Economists, and, when the results are available, it will be possible to see to what extent, if any, the costs of drying have been reduced in the course of a year.

The profitableness of producing dried grass is not so difficult to assess if it is sold, thus obviating the necessity for estimating its value. Sufficient dried grass was sold in 1936 to enable it to be said that, at the above costs of production it was sold at a profit, though, perhaps a moderate one. In grass drying, rain or no rain, an end-product of high feeding value is secured, even the material obtained from long grass—a feeding stuff which may be called super-hay—is superior to good hay made in the ordinary way. Furthermore, the produce of the grassland is conserved without loss. This advantage is not reflected in the per ton costs.

When the product is consumed on the farm, it is more difficult to arrive at a true estimate of profit or loss. Good quality dried grass, containing about 17 per cent. of crude protein, is worth about £6 15s. 0d. a ton when valued by the conventional method, and taking no account of the carotene. At this price, the product shows only a moderate profit on a season's production of 150 tons, the use of about £1,000 capital, and of about 70 acres of land.

The advisability of undertaking grass drying cannot be decided by merely considering the value of the product and its production cost. The alternative methods of utilizing grassland, viz., grazing and hay making, or ensiling, must be considered and compared with grass drying in regard to profits, capital necessary, etc. A comparison with grazing would not, perhaps interest the average farmer, because his object in drying would be to provide cheaper winter food for the stock that is on pasture in the grazing season. Although artificial drying was originally intended to provide a product for replacing concentrates only, the proportions of both hay and concentrates are reduced in practice, and the relative profitableness of haymaking and grass drying will be considered by many who contemplate the latter. A detailed comparison is not advisable when the production costs for dried grass are available for one season only. If, however, we take the average cost of producing one ton of good and of medium quality meadow hay found, for instance, on thirteen farms in Kent, and assume the yield of hay and aftermath to be equal to that of dried grass, the surplus of food value over production costs per ton is £1 16s. 4d., £1 5s. 10d. and 14s. 4d. respectively for good and medium hay, and dried grass. Nothing is allowed for the value of the carotene in this comparison, nor for the fact that the dried grass is baled. If 10s. 0d. per ton is deducted from production costs for baling the dried grass, this product would appear to have been, even in its first year, as profitable as medium quality hay, but less profitable than the best hay. There is no need to be reminded that good dried grass can be made every year, while this does not hold with hay. On the other hand, the capital needed for producing hay is much less. Further investigation on the newer methods of ensiling are needed before a comparison in cost and value between silage and dried grass can be made.

Management.—Early in the course of the survey, it became evident that the problem of managing land for grass drying was very much more difficult than was anticipated. This was evident from the fact that, on most of the farms visited, the grass was being mown in the stemmy, and not in the short, leafy condition. In many interesting discussions with producers, the Crop Drying Investigator was asked for information on such problems as the possibility of levelling out the spring flush by manuring, of raising the proportion of protein by manuring, etc.

It was felt that, in the literature of the various research institutes, etc., there must have been a considerable amount of information that would throw light on various aspects of the management of pastures for drying, though the data would be scattered, because grass drying had not been thought of when most of the work was done. Accordingly, the literature, particularly of the Welsh Plant Breeding Station at Aberystwyth, was examined systematically, and information bearing on the subject was included in the Report. The information available was sufficient, for example, to show clearly that manuring could not even out the spring flush, nor raise the proportion of protein in a grass by more than about 7 per cent. of the total. Furthermore, although species and strains of grasses differ in their tendency to form stems under systems of frequent mowing, it has been impossible to maintain the herbage free from stems at about the usual time when the hay crop matures; the frequently cut pasturage tends to become a hay crop in miniature in June. Further evidence was collected on the effect of frequent mowing on yields and on the sward.

The future of grass drying.—When the results of the 1937 investigations are available, it will be possible to determine whether there has been improvement in the efficiency and output of the driers, and also in the management of the land for grass drying. It is difficult to forecast the future rate of progress of this new development, since it depends so much on improvement in grass-drying machines, the results of research, and also on the prices of feeding stuffs. The output of the farm-size drier needs to be considerably higher in proportion to capital than it was in 1936, and there is also room for some improvement in efficiency. The arrangements referred to above, whereby tests can be carried out by the Royal Technical College, Glasgow, will serve to measure improvements in this respect.

A drier producing a high grade product, and evaporating 1,800 lb. of water per hour as a matter of routine, would probably find a ready sale if it could be sold for £400 including baler, drive for fan, and erection, but excluding the additional sheds that many farms would require.

The possibilities of field wilting as a means of decreasing drying costs, and increasing output, are not fully known at present. Research is needed to show what losses can occur in the wilted material in the interval between mowing and putting it in the drier; the type of research needed is that of the fundamental type rather than that of the empirical type involving only differences in weight. It is evident that, with the high proportion of water-soluble fructosan present in young grass in spring, losses might occur, should factors such as continued respiration after mowing play an important part. The relative losses, when crops of various ages are wilted at different times of the year, are bound up in the same general question, and investigation might show, for instance, that partial field drying might be advantageous under all conditions except for young grass in late May or early June; work so far carried out at Rothamsted indicates such possibilities. Wilting may cause very little loss in a crop that, though not so mature as hay, is in the stemmy condition and easily collected by a rake. Some producers are convinced that grass driers can be used profitably with such crops, and point to the value of replacing haymaking by a process that gives at the rate of about a ton an hour an excellent product mid-way in value between good hay and a concentrate, and that not in some years only, but in every year.

Again, further work is required on the nutritive value of young grass, cut at various times of the year, to assure the farmer that young autumn grass is, in general, as good as young spring grass containing the same amount of crude protein; the grazier believes that, however short and well managed a pasture may be in late summer and autumn, it will not produce milk nor fatten animals as well as spring grass. Should a high value for autumn grass be confirmed, it is safe to predict that grass drying will spread, even should but little progress be made on the engineering side. This question is more important in grass drying than in other methods of conservation because, owing to the limited rate of throughput, the process has to extend over a long period, and cannot be completed in a week or two. Finally, it may be said that the estimate, given in the Committee's first report, of 25 per cent. as the average loss in haymaking in Great Britain has now been considered to be too low by a Sub-Committee of the Committee on the Preservation of Grass and other Fodder Crops; it is thought to be nearer 35 per cent. Such an annual loss as this indicates that, failing improved methods of haymaking, it is important to make either grass drying or ensiling an attractive commercial proposition to the average farmer, and so enable grassland to be used without waste for producing a concentrated, or semi-concentrated feeding stuff for winter use.

X.—CONCLUSION

In the first Report of the Agricultural Research Council an account was given of the position in Great Britain of research into the chief matters of importance to the farming community as it stood in 1933. During the intervening period the Council have made themselves more familiar with the organisation and activities of the research institutes and other agencies engaged in this field, more particularly those financed wholly or in part from State funds. The Council's Second Report, covering the years 1934 and 1935, dealt chiefly with those research activities which had come under special review in those years or had received direct aid by way of grants from the funds at the Council's own disposal. In the present Report for the period from October, 1935, to September, 1937, the fifth and sixth years of the Council's existence, it has seemed timely not only to describe the special activities of the Council during this interval, but also again to endeavour to summarise the principal investigations going on in the more important branches of agricultural science. In doing so, attention has been given more especially to those concerning the soil, crops and dairying, which were less fully discussed in the earlier reports, than those relating to the diseases and nutrition of farm livestock, to the co-ordination and development of which the Council had given priority.

In their relations on the one hand with the Departments of Agriculture, in whose administrative charge is vested the Parliamentary responsibility for agricultural research at the institutes and colleges receiving grant aid from the Development Fund and, on the other with the institutions and individuals whose research work they are charged to review, the Council have been fortunate. The difficulties which were almost inevitable in the process of introducing a new element into the existing machinery of organised agricultural research have been in great part smoothed out by the good will of all concerned. The two successive Notes on Administrative arrangements, defining provisionally the position of the Council in the administrative machine, have aimed at removing these difficulties and have on the whole succeeded in doing so in practice. The Council have to record the good nature with which criticisms of work or organisation, when these have been felt to be necessary, have been received. Such criticisms have been, on the whole, few in number; there is a great deal of valuable work in progress with little redundancy or duplication; and where weaknesses have come to light the fault can be traced in the majority of cases to the difficulty of attracting and retaining the best research ability in the service of agriculture.

Steps are being taken to rectify this; an examination of the pay and prospects of the staffs of the agricultural research institutes has been in progress, and there has been a great improvement in the facilities for the training of students in veterinary science.

The Council works in close consultation in all administrative and financial matters with the Ministry of Agriculture and Fisheries and the Department of Agriculture for Scotland. Effective liaison is maintained with the sister research organisations of the Committees of the Privy Council for Medical Research and for Scientific and Industrial Research, both by consultations and by joint representation on some of the Committees dealing with matters of common interest to medical and agricultural research. The Council also act as scientific advisers to the Development Commission on schemes of agricultural research.

The period covered by this Third Report of the Council has seen a development of primary importance in increasing the Council's activities in the promotion of agricultural research. The acquisition of a Field Station for work under their own control and the appointment of scientific investigators to the Council's staff will enable work to be carried a stage further towards farming practice, especially in the control of animal diseases, than has hitherto been practicable, and will strengthen the Council's opportunities of filling gaps in the research programme and of exerting a greater influence in co-ordinating investigations of wide interest.

The activities and responsibilities of the Agricultural Research Council are increasing. It is hoped that the account given in this Report sufficiently shows not only the great diversity of the work which they are charged to survey, but also its great interest. The ultimate criterion of that work must be its value to the farming community. Improvements in the oldest of all industries, agriculture, are neither rapidly nor easily gained, but in almost every branch of the work reviewed in the previous pages progress is recorded, and the Council believe that the results already achieved and those in sight fully justify the efforts that have been, and are being made to secure them.

RICHARD CAVENDISH,
Chairman of the
Agricultural Research Council.

E. J. BUTLER,
Secretary of the Council,
6A, Dean's Yard,
Westminster, S.W.1.
16*th May,* 1938.

APPENDIX I

COMMITTEES OF THE AGRICULTURAL RESEARCH COUNCIL

(As at the 1st April, 1938)

STANDING COMMITTEES

Soils and Plant Nutrition

Sir Thomas H. Middleton, K.C.I.E., K.B.E., C.B., D.Sc., LL.D., F.R.S. (*Chairman*),
Sir Merrik Burrell, Bart., C.B.E., J.P.,
Sir William Cecil Dampier, Sc.D., F.R.S.,
Sir A. Daniel Hall, K.C.B., D.Sc., LL.D., F.R.S.,
Spencer W. Mount,
Sir Robert Robertson, K.B.E., M.A., D.Sc., LL.D., F.R.S.

Plant Physiology, Breeding and Disease

Sir A. Daniel Hall, K.C.B., D.Sc., LL.D., F.R.S. (*Chairman*),
Sir Joseph Arkwright, M.A., M.D., F.R.C.P., F.R.S.,
Joseph F. Duncan,
J. C. F. Fryer, O.B.E., M.A.,
Spencer W. Mount.

Animal Diseases

Sir Merrik Burrell, Bart., C.B.E., J.P. (*Chairman*),
Sir Joseph Arkwright, M.A., M.D., F.R.C.P., F.R.S.,
W. Horner Andrews, D.Sc., M.R.C.V.S.,
Professor E. P. Cathcart, C.B.E., M.D., D.Sc., LL.D., F.R.S.,
Sir William Cecil Dampier, Sc.D., F.R.S.,
Sir Patrick Laidlaw, M.A., B.Ch., F.R.C.P., F.R.S.,
Professor T. J. Mackie, M.D., D.P.H., M.R.C.P.E., F.R.S.E.,
John Smith, O.B.E., M.R.C.V.S., D.V.H.,
Professor W. W. C. Topley, M.A., M.D., F.R.C.P., F.R.S.

Animal Nutrition and Breeding

Professor Sir Frederick Gowland Hopkins, O.M., D.Sc., F.R.C.P., F.R.S. (*Chairman*),
Sir Merrik Burrell, Bart., C.B.E., J.P.,
Professor E. P. Cathcart, C.B.E., M.D., D.Sc., LL.D., F.R.S.,
Sir William Cecil Dampier, Sc.D., F.R.S.,
Sir Patrick Laidlaw, B.Ch., F.R.C.P., F.R.S.
Sir Thomas H. Middleton, K.C.I.E., K.B.E., C.B., D.Sc., LL.D., F.R.S.,
Professor R. C. Punnett, M.A., F.R.S.,
John Smith, O.B.E., M.R.C.V.S., D.V.H.,
Professor W. W. C. Topley, M.A., M.D., F.R.C.P., F.R.S.,
Professor D. M. S. Watson, D.Sc., F.R.S.

Dairying and Animal Products

Sir William Cecil Dampier, Sc.D., F.R.S. (*Chairman*),
Sir Joseph Arkwright, M.A., M.D., F.R.C.P., F.R.S.,
Sir Merrik Burrell, Bart., C.B.E., J.P.,
Professor E. P. Cathcart, C.B.E., M.D., D.Sc., LL.D., F.R.S.,
Professor T. J. Mackie, M.D., D.P.H., F.R.S.E.,
Sir Thomas H. Middleton, K.C.I.E., K.B.E., C.B., D.Sc., LL.D., F.R.S.,
John Smith, O.B.E., M.R.C.V.S., D.V.H.,
Professor D. M. S. Watson, D.Sc., F.R.S.

Economics

Joseph F. Duncan (*Chairman*),
Sir Merrik Burrell, Bart., C.B.E., J.P.,
Sir William Cecil Dampier, Sc.D., F.R.S.,
Sir A. Daniel Hall, K.C.B., D.Sc., LL.D., F.R.S.,
Sir Thomas H. Middleton, K.C.I.E., K.B.E., C.B., D.Sc., LL.D., F.R.S.,
Professor F. W. Ogilvie, M.A.

Estate

Sir Merrik Burrell, Bart., C.B.E., J.P. (*Chairman*),
Sir William Cecil Dampier, Sc.D., F.R.S.,
Sir Thomas H. Middleton, K.C.I.E., K.B.E., C.B., D.Sc., LL.D., F.R.S.,
Spencer W. Mount,
John Smith, O.B.E., M.R.C.V.S., D.V.H.

Budget

Sir William Cecil Dampier, Sc.D., F.R.S. (*Chairman*),
Sir Merrik Burrell, Bart., C.B.E., J.P.,
Joseph F. Duncan,
Sir Thomas H. Middleton, K.C.I.E., K.B.E., C.B., D.Sc., LL.D., F.R.S.,
Spencer W. Mount.

COMMITTEES APPOINTED ANNUALLY

Estimates of Research Institutes

Sir Thomas H. Middleton, K.C.I.E., K.B.E., C.B., D.Sc., LL.D., F.R.S. (*Chairman*),
Sir Joseph Arkwright, M.A., M.D., F.R.C.P., F.R.S.,
Sir Merrik Burrell, Bart., C.B.E., J.P.,
Professor E. P. Cathcart, C.B.E., M.D., D.Sc., LL.D., F.R.S.,
Sir William Cecil Dampier, Sc.D., F.R.S.,
Joseph F. Duncan,
Professor T. J. Mackie, M.D., D.P.H., M.R.C.P.E., F.R.S.E.,
Spencer W. Mount,
John Smith, O.B.E., M.R.C.V.S., D.V.H.,
Professor Sir William Wright Smith, M.A., D.ès. Sc., F.R.S.E., F.L.S.,
Professor D. M. S. Watson, D.Sc., F.R.S.

Scholarships

Sir A. Daniel Hall, K.C.B., D.Sc., LL.D., F.R.S. (*Chairman*),
W. Horner Andrews, D.Sc., M.R.C.V.S.,
Sir Merrik Burrell, Bart., C.B.E., J.P.,
Sir Thomas H. Middleton, K.C.I.E., K.B.E., C.B., D.Sc., LL.D., F.R.S.,
Sir Robert Robertson, K.B.E., M.A., D.Sc., LL.D., F.R.S.,
John Smith, O.B.E., M.R.C.V.S., D.V.H.,
Professor W. W. C. Topley, M.A., M.D., F.R.C.P., F.R.S.,
Professor D. M. S. Watson, D.Sc., F.R.S.

TECHNICAL COMMITTEES

Preservation of Grass and other Fodder Crops

Sir William Cecil Dampier, Sc.D., F.R.S. (*Chairman*),
Thompson Close, M.B.E.,
H. J. Denham, M.A., D.Sc.,
H. J. Gough, M.B.E., D.Sc., F.R.S.,
Leonard Harding, Ph.D., M.I.Chem.E.,
C. Jakeman,
Martin G. Jones, M.Sc.,
Professor W. Kerr, Ph.D., M.I.Mech.E.,
S. Livingstone Smith, D.Sc., M.I.Mech.E., A.C.G.I.
Professor R. G. Stapledon, C.B.E., M.A.,
J. G. Stewart, O.B.E., B.Sc., M.A.,
Professor J. A. Scott Watson, M.C., M.A.,
H. E. Woodman, M.A., Ph.D., D.Sc.

Nutrition in Relation to Disease

(*Appointed in consultation with the Medical Research Council*)

Professor Sir Frederick Gowland Hopkins, O.M., D.Sc., F.R.C.P., F.R.S. (*Chairman*),
Harriette Chick, C.B.E., D.Sc.,
Professor S. J. Cowell, M.A., M.B., B.Ch., M.R.C.P., M.R.C.S.,
H. H. Green, D.Sc.,
J. Russell Greig, Ph.D., M.R.C.V.S., F.R.S.E.,
Sir Thomas H. Middleton, K.C.I.E., K.B.E., C.B., D.Sc., LL.D., F.R.S.,
Sir John B. Orr, D.S.O., M.C., M.A., M.D., D.Sc., LL.D., F.R.S.,
Professor W. W. C. Topley, M.A., M.D., F.R.C.P., F.R.S.

Insecticides and Fungicides

E. J. Butler, C.M.G., C.I.E., D.Sc., M.B., LL.D., F.R.S. (*Chairman*),
W. F. Bewley, C.B.E., D.Sc.,
W. P. K. Findlay, M.Sc., A.R.C.Sc.,
J. C. F. Fryer, O.B.E., M.A.,
C. T. Gimingham, O.B.E., B.Sc., F.I.C. (*Secretary*),
R. W. Marsh, M.A.,
H. Martin, D.Sc., A.R.C.S., F.I.C.,
A. M. Massee, D.Sc., F.R.E.S.,
Spencer W. Mount,
Professor J. W. Munro, M.A., D.Sc., F.R.S.
F. Tattersfield, D.Sc., F.I.C.

Plant Virus Diseases

E. J. Butler, C.M.G., C.I.E., D.Sc., M.B., LL.D., F.R.S. (*Chairman*),
Sir Joseph Arkwright, M.A., M.D., F.R.C.P., F.R.S.,
J. C. F. Fryer, O.B.E., M.A.,
Professor P. A. Murphy, D.Sc., A.R.C.Sc.I.,
G. H. Pethybridge, Ph.D., M.A., B.Sc., F.L.S.,
G. Samuel, M.Sc.

Helminths of Economic Importance (Plants Section)

Professor D. M. S. Watson, D.Sc., F.R.S. (*Chairman*),
E. J. Butler, C.M.G., C.I.E., D.Sc., M.B., F.R.S.,
J. Carroll, M.Sc., A.R.C.Sc.I., D.I.C., N.D.A.,
J. C. F. Fryer, O.B.E., M.A.,
T. Goodey, D.Sc.,
R. H. Hurst, Ph.D.,
Professor R. T. Leiper, M.D., D.Sc., F.R.S.,
H. W. Miles, D.Sc., Ph.D.,
D. O. Morgan, M.Sc., Ph.D.,
F. R. Petherbridge, M.A.,
David Robertson, Ph.D., B.Sc. (Agr.), N.D.A.,
Marjorie J. Triffitt, D.Sc. (*Secretary*),
C. B. Williams, M.A., Sc.D.,

Helminths of Economic Importance (Animals Section)

Professor D. M. S. Watson, D.Sc., F.R.S. (*Chairman*),
Professor R. A. Fisher, M.A., Sc.D., F.R.S.,
G. Lapage, M.Sc., M.D., Ch.B., M.A.,
Professor R. T. Leiper, M.D., D.Sc., F.R.S.,
D. O. Morgan, M.Sc., Ph.D. (*Secretary*),
J. N. Oldham, B.Sc., Ph.D.,
Sir John B. Orr, D.S.O., M.C., M.A., M.D., D.Sc., LL.D., F.R.S.,
E. L. Taylor, B.V.Sc., M.R.C.V.S., D.V.H.,

Diseases of Sheep
(Diseases not coming within the purview of other technical Committees of the Council)

Professor T. J. Mackie, M.D., D.P.H., M.R.C.P.E., F.R.S.E. (*Chairman*),
T. J. Bosworth, B.Sc., M.R.C.V.S., D.V.S.M.,
Professor Thomas Dalling, M.A., M.R.C.V.S.,
J. Russell Greig, Ph.D., M.R.C.V.S., F.R.S.E.,
A. D. McEwen, D.Sc., M.R.C.V.S. (*Secretary*),
R. F. Montgomerie, B.Sc., F.R.C.V.S., Ph.D.,
W. Lyle Stewart, M.R.C.V.S.

Contagious Abortion
(Brucella abortus Infection in Animals and Man)

(*Appointed in consultation with the Medical Research Council*)

Sir Joseph Arkwright, M.A., M.D., F.R.C.P., F.R.S. (*Chairman*),
W. Horner Andrews, D.Sc., M.R.C.V.S.,
Professor J. B. Buxton, M.A., F.R.C.V.S., D.V.H.,
Sir Weldon Dalrymple-Champneys, Bart, M.D., F.R.C.P.,
Professor J. F. Craig, M.A., F.R.C.V.S.,
Captain T. M. Doyle, F.R.C.V.S., D.V.S.M.,
Arthur Gofton, F.R.C.V.S.,
J. Russell Greig, Ph.D., M.R.C.V.S., F.R.S.E.,
Professor R. G. Linton, Ph.D., M.R.C.V.S.,
A. D. McEwen, D.Sc., M.R.C.V.S.,
Professor F. C. Minett, M.B.E., D.Sc., M.R.C.V.S.,
W. A. Pool, M.R.C.V.S. (*Secretary*),
W. J. Tulloch, O.B.E., M.D., D.P.H.,
Professor G. S. Wilson, M.D., F.R.C.P., D.P.H.

Fowl Paralysis and Similar Diseases and Coccidiosis

Professor D. M. S. Watson, D.Sc., F.R.S. (*Chairman*),
Professor S. L. Baker, M.R.C.S., L.R.C.P., Ph.D., D.P.H.,
Professor S. P. Bedson, M.D., M.Sc., B.S., F.R.S.,
Professor Thomas Dalling, M.A., M.R.C.V.S. (*Secretary*),
N. Dobson, B.Sc., M.R.C.V.S.,
P. A. Francis, O.B.E.,
R. E. Glover, B.Sc., M.R.C.V.S.,
H. H. Green, D.Sc.,
Professor D. Keilin, Sc.D., F.R.S.,
C. A. McGaughey, M.R.C.V.S., D.V.S.M.,
Professor F. C. Minett, M.B.E., D.Sc., M.R.C.V.S.,
E. L. Taylor, B.V.Sc., M.R.C.V.S., D.V.H.,
J. E. Wilson, B.Sc., M.R.C.V.S.

Johne's Disease in Cattle and Sheep

Sir Joseph Arkwright, M.A., M.D., F.R.C.P., F.R.S. (*Chairman*),
Professor J. B. Buxton, M.A., F.R.C.V.S., D.V.H.,
Professor J. F. Craig, M.A., F.R.C.V.S.,
G. W. Dunkin, M.R.C.V.S., D.V.H.,
Professor F. C. Minett, M.B.E., D.Sc., M.R.C.V.S. (*Secretary*)

Swine Fever, Necrotic Enteritis and Similar Diseases of Pigs

W. Horner Andrews, D.Sc., M.R.C.V.S. (*Chairman*),
Professor J. B. Buxton, M.A., F.R.C.V.S., D.V.H.,
C. Crowther, M.A., Ph.D.,
Professor Thomas Dalling, M.A., M.R.C.V.S.,
Captain T. M. Doyle, F.R.C.V.S., D.V.S.M.,
H. H. Green, D.Sc. (*Secretary*),
Sir Patrick Laidlaw, M.A., Ch.B., F.R.C.P., F.R.S.,
Professor R. T. Leiper, M.D., D.Sc., F.R.S.,
Sir John B. Orr, D.S.O., M.C., M.A., M.D., D.Sc., LL.D., F.R.S.,
E. L. Taylor, B.Sc., M.R.C.V.S., D.V.H.,
Captain W. G. Wragg, M.R.C.V.S.

Tuberculosis

(*Jointly with the Medical Research Council*)

Sir Joseph Arkwright, M.A., M.D., F.R.C.P., F.R.S. (*Chairman*),
Sir Merrik Burrell, Bart., C.B.E., J.P.,
L. S. T. Burrell, M.D., F.R.C.P.,
Professor J. B. Buxton, M.A., F.R.C.V.S., D.V.H.,
Professor S. L. Cummins, C.B., C.M.G., M.D., LL.D.,
Professor Thomas Dalling, M.A., M.R.C.V.S.,
G. W. Dunkin, M.R.C.V.S., D.V.H. (*Joint Secretary*),
A. Stanley Griffith, M.D., Ph.D.,
N. F. Smith, M.D., M.R.C.S., L.R.C.P. (*Joint Secretary*),
Professor G. S. Wilson, M.D., F.R.C.P., D.P.H.

Iodine Deficiency and Thyroid Disease

(*Jointly with the Medical Research Council*)

Sir John B. Orr, D.S.O., M.C., M.A., M.D., D.Sc., LL.D., F.R.S. (*Chairman*),
Professor G. Barger M.A., D.Sc., LL.D., F.R.S.,
H. H. Green, D.Sc.,
Professor C. R. Harington, M.A., Ph.D., F.R.S.,
Sir Robert Robertson, K.B.E., M.A., D.Sc., LL.D., F.R.S.,
A. W. Spence, M.D., F.R.C.P. (*Secretary*).

Equine Research

Sir Merrik Burrell, Bart., C.B.E., J.P. (*Chairman*),
C. C. Edmunds,
Sir John Kelland, M.R.C.V.S.,
Sir Patrick Laidlaw, M.A., B.Ch., F.R.C.P., F.R.S.,
The Hon. Alexander Parker,
Major A. A. Pryer, D.S.O.,
E. Brayley Reynolds, O.B.E., M.R.C.V.S.,
John Smith, O.B.E., M.R.C.V.S., D.V.H.,
Major G. Williamson, O.B.E.

Members of Sub-Committees or Visiting Committees, not members of the Council or its Committees, who served during the period covered by the present Report.

D. A. E. Cabot, M.R.C.V.S.,
Professor F. L. Engledow, C.M.G., M.A.,
Sir John Flett, K.B.E., M.A., D.Sc., LL.D., F.R.S.,
Professor James Gray, M.C., M.A., Sc.D., F.R.S.,
J. M. Hamill, O.B.E., M.D., D.Sc.,
Professor J. Hanley, A.R.C.S., Ph.D.,
Professor O. T. Jones, M.A., D.Sc., F.R.S.,
Professor S. P. Mercer, B.Sc., N.D.A.,
Professor H. A. D. Neville, M.A., B.Sc., F.I.C.,
Professor E. K. Rideal, M.B.E., M.A., D.Sc., F.I.C., F.R.S.,
J. A. Ritchie, B.Sc., M.R.C.V.S., D.V.S.M.,
Lieut.-Colonel P. J. Simpson, J.P., F.R.C.V.S.,
A. D. Buchanan Smith, M.A., M.Sc., B.Sc., F.R.S.E.,
Professor W. Stiles, M.A., Sc.D., F.R.S.,
L. A. Thompson, M.Sc.

APPENDIX II.

GRANTS SANCTIONED OR RECOMMENDED BY THE AGRICULTURAL RESEARCH COUNCIL DURING THE PERIOD 1ST OCTOBER, 1935, TO THE 30TH SEPTEMBER, 1937, FOR PAYMENT EITHER DIRECTLY FROM THE FUNDS OF THE COUNCIL OR FROM THE SUMS PROVIDED ON THE VOTES OF THE MINISTRY OF AGRICULTURE AND FISHERIES AND THE DEPARTMENT OF AGRICULTURE FOR SCOTLAND FOR SPECIAL RESEARCH SCHEMES WHICH THE COUNCIL DECIDE TO ASSIST OR INITIATE.

Date.	Body to which grant made.	Subject of investigation.	Amount and period of grant.
		PLANT DISEASES.	
21. 7.37	(*a*) Institute of Agricultural Parasitology, London School of Hygiene and Tropical Medicine.	Investigations into Root eelworm disease of potatoes, under the general co-ordination of the Council's Committee on Helminths of Economic Importance (Plants Section).	(*a*) £600 for one year from the 1st August, 1937.
22. 7.36 21. 7.37	(*b*) University of Manchester.		(*b*) £440 for the period 1st August, 1936, to the 31st July, 1938.
21. 7.37	(*c*) West of Scotland Agricultural College.		(*c*) £100 for one year from the 1st July, 1937.
20. 1.37	(*a*) Long Ashton Horticultural Research Station, University of Bristol.	Investigations into insecticides and fungicides. Under the general co-ordination of the Council's Committee on Insecticides and Fungicides.	(*a*) £125 For the period 1st October, 1936, to the 31st March, 1937.
20. 1.37	(*b*) East Malling Research Station, Kent		(*b*) £420
16.10.35 22. 7.36 21. 7.37	Imperial College of Science and Technology.	Investigations on Soil parasiticides with special reference to fumigants.	£1,718 for the period 1st October, 1935, to the 30th September, 1938.
22. 7.36	Rothamsted Experimental Station, Harpenden, Herts.	Soil insect investigations in connection with the use of naphthalene and other coal-tar derivatives as insecticides.	£150 for one year from the 1st October, 1936.
22. 7.36 21. 7.37	Imperial College of Science and Technology.	Development of research on the physiology of insects and the extension of work on insecticides.	£1,300 for the period 1st October, 1936, to the 30th September, 1938.

Date.	Body to which grant made.	Subject of investigation.	Amount and period of grant.
		PLANT DISEASES—*continued.*	
11.11.36	University College of the South-West of England, Exeter.	Research on Virus diseases of horticultural plants. Under the co-ordination of the Council's Sub-Committee on Virus Diseases of Plants.	£455 for one year from the 1st February, 1937.
21. 7.37	East Malling Research Station, Kent.	Research on Virus diseases of small fruits.	£345 for one year from the 1st April, 1938.
21. 7.37	Molteno Institute of Biology and Parasitology, University of Cambridge.	Investigation of the relationship of tobacco mosaic virus with the crystalline protein obtained from the sap of diseased plants.	£50 for the period 1st April, 1937, to the 30th September, 1937.
16.10.35 11.11.36	Seale Hayne Agricultural College, Devon.	Diseases of Flowers.	£395 for the period 1st January, 1936, to the 31st December, 1937.
16.10.35	Imperial College of Science and Technology.	Research on problems of Plant Bacteriology.	£201 for one year from the 1st October, 1935.
22. 7.36 21. 7.37	ditto	Investigation of the Marssonina disease of lettuce.	£600 for the period 1st October, 1936, to the 30th September, 1938.
22. 7.36 21. 7.37	ditto	Investigation of the Cauliflower disease of strawberries and similar diseases.	£504 for the period 1st October, 1936, to the 30th September, 1938.
6. 6.37	University of Reading.	Investigation of Strawberry diseases in the Botley area of Hampshire.	£505 for the period 1st June, 1937, to the 31st March, 1938.
21. 4.37	University of Manchester.	Investigation of wireworm damage to crops, especially potatoes.	£75 capital + £227½ for the period 1st April, 1937, to the 30th September, 1937.

Date.	Body to which grant made.	Subject of investigation.	Amount and period of grant.
		PLANT DISEASES—*continued.*	
22. 4.36	University College of North Wales, Bangor.	Survey of aphis population on potatoes in selected areas in Scotland.	£39.
22. 4.36 21. 4.37	ditto.	Study of the ecology of potato aphides.	£61 for the period 1st April, 1936, to the 31st March, 1938.
22. 7.36	Edinburgh and East of Scotland College of Agriculture.	Study of the biology and habits of slugs attacking the potato crop.	£200 for one year from the 1st October, 1936.
16.10.35	Botany School, University of Cambridge.	Investigation of " Chocolate Spot " disease of beans.	£125 for one year from the 1st October, 1935.
22. 7.36	Botany School, University of Cambridge.	Insect transmission of watermark disease of the cricket bat willow.	£196 for the period 4th September, 1936, to the 31st March, 1937.
20.1. 37	Welsh Plant Breeding Station, Aberystwyth.	Survey in England, Wales and Scotland of fungus diseases attacking herbage grasses and clovers.	£400 for one year from the 11th February, 1937.
		PLANT BREEDING.	
11.11.36	John Innes Horticultural Institution, Merton.	Investigations on the breeding of maize with special reference to the production of early varieties of " Sweet Corn " for growth as a vegetable in the United Kingdom.	£200 for one year from the 1st October, 1936.
11.11.36	Plant Breeding Institute, University of Cambridge.	New work on brassica crops.	£312½ for the period 1st July, 1936, to the 30th September, 1937.

Date.	Body to which grant made.	Subject of investigation.	Amount and period of grant.
		PLANT PHYSIOLOGY.	
11.11.36 21. 4.37	Imperial College of Science and Technology.	Investigation of the proteins of leaves.	£318 for one year from the 1st October, 1936. £425 for the period 1st May, 1937, to the 30th September, 1938.
		PLANTS (MISCELLANEOUS).	
22. 7.36	Edinburgh and East of Scotland College of Agriculture.	Investigations into the chemical reaction of potato tubers.	£200 for one year from the 1st October, 1936.
21. 4.37	Welsh Plant Breeding Station, Aberystwyth.	Preparation of Exhibit at Fourth International Grassland Conference.	£110.
		SOILS.	
22. 4.36	University of Reading.	Soil Survey of Hampshire strawberry growing areas.	£600 for the period 1st September, 1936, to the 31st August, 1938.
22. 4.36	University College of North Wales, Bangor.	Survey of Bulb growing soils.	£250 for 6 months from the 13th July, 1936.
20. 1.37	University College of North Wales, Bangor.	Investigation of Horticultural Soils.	£350 for one year from the 1st June, 1937.
20. 1.37	Bedford College for Women, London.	Growth inhibition of humus rich soil at Wareham, Dorset.	£350 for one year from the 1st April, 1937.
22. 4.36 21. 4.37	School of Rural Economy, University of Oxford.	Study of the changes in the composition and properties of clay particles during dehydration.	£300 for one year from the 1st October, 1936.
15. 1.36 27. 3.36	Macaulay Institute for Soil Research, Scotland.	Spectrographic investigations.	£300 for one year from the 1st April, 1936. £50 supplementary capital grant for the year from the 1st April, 1935.

Date.	Body to which grant made.	Subject of investigation.	Amount and period of grant.
		ANIMAL DISEASES.	
16.10.35 16.12.35 11.11.36	(*a*) Royal Veterinary College, London.	For work on Contagious Abortion under the co-ordination of the Council's Committee on *Brucella abortus* Infection in Animals and Man.	(*a*) £307½ for the period 1st October, 1935, to the 31st March, 1938.
16.10.35 15. 1. 36 11.11.36	(*b*) South-Eastern Agricultural College, Wye.		(*b*) £4,875 for the period 1st October, 1935, to the 30th September, 1938.
16.10.35 11.11.36	(*c*) Liverpool University.		(*c*) £445 for the period 1st October, 1935, to the 31st March, 1938.
15. 1. 36	(*d*) Institute of Animal Pathology, University of Cambridge.		(*d*) £50 for the period 1st April, 1936, to the 31st March, 1937.
15. 1. 36 25. 2. 36 11.11.36	(*e*) Ministry of Agriculture and Fisheries Veterinary Laboratory, Weybridge.		(*e*) £4,930 for the period to the 31st March, 1938.
16.10.35	(*f*) Rowett Research Institute, Aberdeen.		(*f*) £125 for one year from the 1st October, 1935.
16.10.35 11.11.36	(*g*) Animal Diseases Research Association, Scotland.		(*g*) £750 for the period 1st October, 1935, to the 31st March, 1938.
16.10.35 11.11.36	(*h*) Hannah Dairy Research Institute, Scotland.		(*h*) £812½ for the period 1st October, 1935, to the 31st March, 1938.
15. 1. 36 11.11.36	(*i*) Mr. F. W. Priestley, M.R.C.V.S., Member of the Agricultural Research Council's Scientific Staff for work on contagious abortion.		(*i*) £1,650 salary and superannuation for the period 1st August, 1936, to the 31st July, 1939. £30 travelling expenses for one year from the 1st August, 1936.

Date.	Body to which grant made.	Subject of investigation.	Amount and period of grant.
		ANIMAL DISEASES—*continued.*	
16.10.35 22. 7.36	Royal (Dick) Veterinary College, Edinburgh.	Survey of the incidence of fowl paralysis in Scotland. Under the general co-ordination of the Council's Committee on Fowl Paralysis and Allied Diseases and on Coccidiosis.	£240 for the period 1st October, 1935, to the 30th September, 1937.
16.10.35	University of Manchester.	Fowl paralysis investigations.	£50 for one year from the 1st October, 1935.
16.10.35	Molteno Institute of Biology and Parasitology, University of Cambridge.	Fowl paralysis investigations.	£160 for one year from the 1st October, 1935.
21. 4.37	(*a*) Rowett Research Institute, Aberdeen.	Investigation of the outbreak of fowl paralysis at the Rowett Research Institute.	(*a*) £750 capital and £2,340 for one year from the 1st April, 1937.
21. 4.37	(*b*) Royal (Dick) Veterinary College, Edinburgh.		(*b*) £275 for one year from the 1st April, 1937.
21. 4.37	(*c*) Institute of Animal Genetics, Edinburgh University.		(*c*) £25 for one year from the 1st April, 1937.
—	Mr. C. Horton-Smith, B.Sc., D.I.C., Member of the Agricultural Research Council's Scientific Staff for work on coccidiosis.	—	£990 salary and superannuation for the period 15th March, 1937, to the 14th March, 1940. £100 research expenses for the period ending the 31st March, 1938. £15 travelling expenses for the period ending the 31st March, 1938.

Date.	Body to which grant made.	Subject of investigation.	Amount and period of grant.
		ANIMAL DISEASES—*continued.*	
16.10.35 22. 4.36 22. 7.36	(*a*) Institute of Animal Pathology, University of Cambridge.	Investigations into Braxy-like diseases of sheep under the co-ordination of the Council's Committee on Braxy-like Diseases of Sheep.	(*a*) £700 for the period 1st April, 1936, to the 30th September, 1936. £50 supplementary grant for the year from 1st April, 1935.
20. 1.37	(*b*) King's College, Newcastle-upon-Tyne.		(*b*) £70 for one year from the 1st October, 1936.
20. 1.37	(*c*) Seale-Hayne Agricultural College, Devon.		(*c*) £30 for one year from the 1st October, 1936.
20. 1.37 21. 7.37	(*d*) University College of North Wales, Bangor.		(*d*) £120 for the period 1st October, 1936, to the 30th September, 1938.
11.11.36 20. 1.37	(*e*) Mr. R. S. Roberts, F.R.C.V.S., Member of the Agricultural Research Council's Scientific Staff for work on diseases of sheep.		(*e*) £1,850 salary and superannuation for the period 1st August, 1936, to the 31st July, 1939. £470 travelling expenses for one year from the 1st October, 1936. £250 research expenses for one year from the 1st October, 1936.
21. 7.37	University College of North Wales, Bangor.	Investigations into the value of lamb dysentery serum in the prevention of pulpy kidney disease of lambs, under the co-ordination of the Council's Committee on Braxy-like Diseases of Sheep.	£215 for one year from the 1st October, 1937.

Date.	Body to which grant made.	Subject of investigation.		Amount and period of grant.
		ANIMAL DISEASES—*continued.*		
11.11.36	Ministry of Agriculture and Fisheries Veterinary Laboratory, Weybridge.	Investigations on Swine Fever and Necrotic Enteritis.	Under the general co-ordination of the Council's Committee on Swine Fever, Necrotic Enteritis, and Similar Diseases of Pigs.	£1,400 for one year from the 1st April, 1937.
11.11.36 21. 7.37	Ministry of Agriculture and Fisheries Veterinary Laboratory, Weybridge.	Investigations into (*a*) the association between necrotic enteritis and ascaris infection and (*b*) the pathogenesis of ascaris for pigs.		£300 for the period to the 31st March, 1938.
11.11.36	Institute of Animal Pathology, University of Cambridge.	Investigations into Swine Erysipelas.		£400 for one year from the 1st October, 1936.
16. 9.36 22. 7.36 21. 4.37	Institute of Animal Pathology, University of Cambridge.	Investigations on BCG vaccine.	Under the co-ordination of the Joint Committee on Tuberculosis of the Agricultural Research Council and the Medical Research Council.	£2,624 for the period 1st April, 1936, to the 31st March, 1938. £400 supplementary grant for the period 1st October, 1934, to the 31st March, 1936.
22. 4.36	National Institute for Research in Dairying, Reading.	Investigations into the viability of the bovine tubercle bacillus under natural conditions.		£100 for the period 1st January to the 30th June, 1936.
16.10.35 11.11.36	Rowett Research Institute, Aberdeen.	Investigations on intestinal parasites of sheep.	Under the general co-ordination of the Council's Committee on Helminths of Economic Importance (Animal Section).	£502 for the period 1st October, 1935, to the 30th September, 1937.
16.10.35	Edinburgh and East of Scotland College of Agriculture.	Investigations on intestinal parasites of poultry.		£70 for the period to the 31st March, 1936.
11.11.36 21. 7.37	Institute of Agricultural Parasitology, London School of Hygiene and Tropical Medicine.	Research on Anthelmintics likely to prove effective against sheep parasites.		£1,200 for the period 1st August, 1936, to the 31st July, 1938.
11.11.36 21. 7.37	Institute of Agricultural Parasitology, London School of Hygiene and Tropical Medicine.	Survey of the distribution of *Limnaea truncatula.*		£867 for the period 1st October, 1936, to the 31st July, 1938.

Date.	Body to which grant made.	Subject of investigation.	Amount and period of grant.
		ANIMAL DISEASES—*continued.*	
16.10.35 11.11.36	Secretary of the Council's Committee on Johne's disease in Cattle and Sheep.	Testing of cattle at the Islington Abattoir with Johnin. Under the general co-ordination of the Council's Committee on Johne's Disease in Cattle and Sheep.	£500 for the period 1st January, 1936, to the 31st December, 1937.
11.11.36	South-Eastern Agricultural College, Wye.	Experiments on Johne's Disease in Cattle and Sheep.	£60 for one year from the 1st January, 1937.
15. 1.36	National Institute for Medical Research, Mill Hill.	Investigations on epidemic coughing in horses. Under the general co-ordination of the Council's Committee on Equine Research.	£100.
15. 1.36	Institute of Animal Nutrition, University of Cambridge.	Investigations on sterility in mares.	£350 for one year from the 1st January, 1937.
15. 1.36	Institute of Animal Pathology, University of Cambridge.	Investigations on scouring in foals.	£50 for one year from the 1st January, 1937.
20. 1.37	Royal (Dick) Veterinary College, Edinburgh.	Investigations on disabling diseases of horses.	£1,075 for one year from the 1st April, 1937.
—	Animal Diseases Research Association, Scotland.	Investigation on grass sickness in horses.	£800 capital + £200 for one year from the 1st April, 1937.
22. 4.36 21. 7.37	Hannah Dairy Research Institute, Scotland.	Work on the diagnosis and control of bovine mastitis under the general supervision of the Scottish Board of Research in Veterinary Science.	£375 for the period 1st April, 1936, to the 31st March, 1938.
22. 4.36	Institutes of Animal Pathology and Animal Nutrition, University of Cambridge.	Investigations on sterility in cows.	£900 for one year from the 1st October, 1936.

Date.	Body to which grant made.	Subject of investigation.	Amount and period of grant.
		ANIMAL DISEASES—*continued.*	
16.10.35	(*a*) Royal Veterinary College, London.	Survey of the incidence of mortality among calves.	(*a*) £600 for the period 1st January, 1936, to the 31st December, 1937.
11.11.36 21. 7.37	(*b*) Hannah Dairy Research Institute, Scotland.		(*b*) £175 for the period to the 30th December, 1937.
16.10.35 11.11.36	(*a*) University College of North Wales, Bangor.	Sheep Blowfly investigations.	(*a*) £215 capital + £1,480 for the period 1st October, 1935, to the 30th September, 1937.
16.12.35	(*b*) Natural History Department, University of Aberdeen.		(*b*) £54 for one year from the 1st January, 1936.
		ANIMAL GENETICS.	
22. 7.36	Institute of Animal Genetics, Edinburgh University.	Research into the pre-natal and post-natal changes in the relative growth rate of summer and winter chickens.	£275 for one year from the 1st October, 1936.
		ANIMAL NUTRITION.	
16.12.35 11.11.36	Rowett Research Institute, Aberdeen.	Investigations on Iodine Deficiency from the agricultural aspect, under the general co-ordination of the Joint Committee on Iodine Deficiency and Thyroid Disease of the Agricultural Research Council and the Medical Research Council.	£500 for the period 1st January, 1936, to the 31st December, 1937.

Date.	Body to which grant made.	Subject to investigation		Amount and period of grant.
		ANIMAL NUTRITION—*continued.*		
22. 7.36	King's College, Newcastle-upon-Tyne.	Investigations into "pining" in border sheep.	Under the general co-ordination of the Council's Committee on Nutrition in Relation to Disease.	£900 for the period 1st August, 1936, to the 31st July, 1939.
21. 4.37	(*a*) Ministry of Agriculture and Fisheries Veterinary Laboratory, Weybridge. (*b*) National Institute for Research in Dairying, Reading.	Investigations on A-avitaminosis in pigs.		(*a*) £150 (*b*) £50 for one year from the 1st April, 1937.
22. 7.36	Royal (Dick) Veterinary College, Edinburgh.	Research on Ketosis in dairy cattle.		£90 for one year from the 1st October, 1936.
20. 1.37	Royal (Dick) Veterinary College, Edinburgh.	Study of the metabolism of fats with special reference to the study of experimentally produced "fatty livers" in the sheep.		£53 for one year from the 1st April, 1937.
21. 7.37	Department of Biochemistry, University of Oxford.	Research on the dietary factors required by poultry and pigeons for the maintenance of normal health.		£250 for one year from the 1st October, 1937.
22. 4.36 22. 7.36 21. 7.37	School of Rural Economy, University of Oxford.	Study of problems of sheep nutrition.		£50 capital + £210 for the period 1st October, 1936, to the 30th September, 1938.
11.11.36	Hannah Dairy Research Institute, Scotland.	Work on starvation metabolism during the intake of a normal diet.		£15 for one year from the 1st October, 1936.
		ANIMALS (MISCELLANEOUS).		
22. 4.36	Bureau of Animal Population, University of Oxford.	In aid of the general work of the Bureau.		£1,100 for the period 1st October, 1936, to the 30th September, 1941.

Date.	Body to which grant made.	Subject of investigation.	Amount and period of grant.
		MISCELLANEOUS.	
16.10.35 11.11.36	Council's Committee on the Preservation of Grass and other Fodder Crops.	For investigations under the general co-ordination of the Committee.	£2,384 for the period 1st April, 1936, to the 31st March, 1938.
21. 4.37	Hannah Dairy Research Institute, Scotland.	Investigations into the cost of producing artificially dried young grass, under the general co-ordination of the Council's Committee on the Preservation of Grass and other Fodder Crops.	£25 for one year from the 1st October, 1936.
21. 4.37	Hannah Dairy Research Institute, Scotland.	In aid of the deficiency on crop drying operations during the 1935 and 1936 seasons.	£250.
17.12.35 11.11.36	Rothamsted Experimental Station, Harpenden, Herts.	Investigations into foul brood disease of bees.	£550 for the period 1st October, 1935, to the 30th September, 1937.
22. 7.36	Rothamsted Experimental Station, Harpenden, Herts.	Investigations of the quality and classification of honey and of processes involved in its preparation for sale.	£520 for one year from the 1st October, 1936.
10. 8.37	Mr. John Grierson.	Investigation of the best means of making known the results of agricultural research.	£75.
20. 1.37	Scottish Board of Research in Veterinary Science.	In aid of the travelling and administrative expenses of the Board.	£100 for one year from the 1st April, 1937.

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